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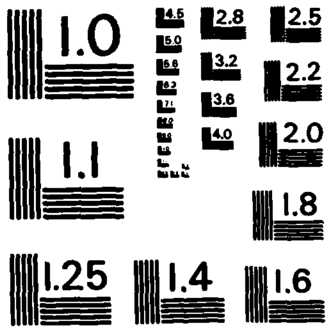

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LOW-LEVEL WIND SYSTEMS IN THE WARSAW PACT COUNTRIES

BY

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MARCH 1985

UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)
USAF
ENVIRONMENTAL
TECHNICAL APPLICATIONS
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SECURITY CLASSIFICATION OF THIS PAGE

AD-A160 144

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAFETAC/TN-85/001	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAF Environmental Technical Applications Center 6b. OFFICE SYMBOL (If applicable) USAFETAC/LDX	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code) Scott Air Force Base, Illinois 62225	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.
11. TITLE (Include Security Classification) See reverse	
12. PERSONAL AUTHOR(S) See reverse	
13a. TYPE OF REPORT Final 13b. TIME COVERED FROM ______ TO ______	14. DATE OF REPORT (Yr., Mo., Day) 85/03 15. PAGE COUNT 58
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Low-level winds, winds, local winds; wind effects, wind direction; wind speed; ~~wind characteristics~~; turbulence;
04	02		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A comprehensive survey of local wind systems in the Warsaw Pact and adjacent NATO/neutral countries. The region surveyed is divided into two geographical areas that cover most of Europe. Local winds are named and related to listed meteorological definitions. Distinctive wind characteristics are identified for the specific local wind or for its locale. Maps showing distribution and location of local wind systems are included. Additional local wind names are listed. Locally-named winds are defined and described.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Wayne E. McCollom	22b. TELEPHONE NUMBER (Include Area Code) 618 256-5023 22c. OFFICE SYMBOL USAFETAC/LDX

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

11. Low-Level Wind Systems in the Warsaw Pact Countries

12. McCollom, Wayne E.; Walters, Kenneth R.; Coyle, Ronald W.; Smith, Eleanor L.; Elder, George E.

18. Antitriptic winds; katabatic ~~winds,~~ and anabatic winds; pressure gradient winds; land and sea breezes; mountain ~~winds,~~ valley winds; orographically-modified winds; foehn; bora; jet-effect; Maloja; Liptowski, Tatra, Koszawa Orkoschava, Sukhovei, Tramontana, Bise, Polak, Boehmischer, Kossava, Crivetz, Nemere, Liva, Vardarac, Struma, Raghieh, Etesian, Novorossiysk Bora, Scirocco, Sirocco, mountain wave; standing wave; laminar streaming; standing eddy streaming; wave streaming; rotor streaming; cap cloud; foehn wall, Warsaw Pact countries.

PREFACE

This Technical Note was prepared by the Document Research Section (LDX) of the USAF Environmental Technical Applications Center (USAFETAC), Air Weather Service, Scott Air Force Base, Illinois, for the Joint Cruise Missiles Project Office, Washington, DC., in support of their Medium Range Air-to-Surface Missile Program. It is the result of extensive research using the latest computer-based bibliographic data bases and thorough manual investigation. No claim for total inclusiveness is made. Anyone with knowledge of other local wind systems in or near the Warsaw Pact countries is encouraged to contact the Air Weather Service Technical Library (AWSTL), Scott Air Force Base, Illinois, 62225.

The AWSTL staff received valuable help from other libraries in its search for reference material. Those providing assistance included the the Federal Library Committee, the Library of Congress, the Library and Information Services Division of the National Oceanic and Atmospheric Administration (NOAA), and the National Meteorological Library of the United Kingdom's Meteorological Office. Although many of the reference documents were in languages other than English, the Headquarters Foreign Technology Division's Technical Translation Division provided prompt and accurate translations. Special thanks to Mrs. Jeanette Davis of the AWSTL staff, who collected the numerous references required to produce this document.

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CHAPTER 1

INTRODUCTION

This Technical Note provides brief descriptions and summaries of low-level wind systems common to the Warsaw Pact countries and their nearby NATO neighbors. Individual wind systems are identified by name and general location. The atmospheric forces that react to topographic features and produce these systems are described in considerable detail. Although measurements and studies that define the physical characteristics (horizontal and vertical speeds, frequency of occurrence, etc.), of these systems are scarce, every attempt has been made to collect, analyze, and include all data available. This publication should help users become familiar with the general locations of local low-level wind systems, their characteristics, and their effects on low flying aircraft.

Primary measurements are given in metric units, but another unit is added in parentheses for convenience. Most values are rounded to the nearest whole unit. Abbreviations used are:

Meter	m
Kilometer	km
Second	s
Feet	ft
Miles	mi
Knots	kts
Meters per second	m/s
Miles per hour	mph
Feet per second	ft/s

Where a non-metric measurement unit is not given, use the following conversion relationships:

Meter (m) = 3.280833 Feet (ft)
Kilometer (km) = 0.621370 Statute miles (mi)
Meter per second (m/s) = 2.236932 Statute miles per hour (mph)
Meter per second (m/s) = 1.9424 Knots (kts)
Meter per second (m/s) = 3.2808336 Feet per second (ft/s)

CHAPTER 2

GEOGRAPHY

2.1. Area Identification. This document discusses low-level wind systems in the Warsaw Pact countries (Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, the USSR), and their immediate neighbors. Based on general terrain features, the entire region addressed has been divided into and described as Areas I and II. See Appendix A, Maps, for area boundaries, general topography, and locations of some of the principal low-level wind types.

Area I: Central and northern Germany, northern Poland, Finland, northern European Russia, and the island of Novaya Zemlya, just north of the continental USSR.

Area II: Southern Germany, southern Poland, Switzerland, Italy, Austria, Czechoslovakia, Hungary, the Balkans, northern Turkey and southern European Russia, the Black Sea region, and the north central Mediterranean Sea.

2.2. Area I Topography. The terrain in Area I consists generally of plains and rolling hills. Elevations are usually less than 500 m (1,640 ft) above mean sea level, with four exceptions:

- The Ural Mountains, aligned NNE to SSW along 60° E. Elevations north of 60° N range from 900 to 1,520 m (2,952 and 4,986 ft), with a maximum height of just over 1,900 m (6,233 ft) at 65° N, 60° E. Elevations lower gradually south of 60° N, falling to below 760 m (2,493 ft) south of 58° N.

- The island of Novaya Zemlya, actually an extension of the Ural Mountains. The island's relief is very rough with little vegetation. The highest elevation is more than 1,000 m (3,281 ft) near Matochkin Fhar at 74° N, 57° E.

- A range of east-to-west hills between Murmansk and the north shore of the extreme northwestern portion of the White Sea. Elevations in these hills range from 300 to 1,200 m (984 to 3,936 ft).

- The intersection of the Kjoellen Mountains and extreme northern Finland. Rivers from these mountains form valleys that extend southward toward the Gulf of Bothnia. The highest elevation is 1,139 m (3,737 ft) near Kahperusvaara.

There are many large bodies of water in Area I. Lakes abound in Southern Finland and in the area between Leningrad and the southern arm of the White Sea. The largest is Lake Ladoga, just northeast of Leningrad. Lake Ladoga is 100 by 600 km (62 by 373 mi) and has a significant effect on local weather.

Finland is surrounded on two sides by extensions of the Baltic Sea. The Gulf of Finland, on the south, has an average width of 65 to 100 km (40 to 62 mi). The Gulf of Bothnia, on the west, has an average width of 100 to 150 km (62 to 93 mi).

The Baltic States consist of plains and rolling hills with elevations less than 300 m (984 ft). Except for the Gulf of Riga, with widths ranging from 50 to 75 km (31 to 47 mi), the Baltic Sea coast is relatively featureless.

The central European region consists of rolling plains cut by rivers flowing north into the Baltic Sea or south into the Black or Caspian Seas. Elevations over these vast plains are generally below 300 m (984 ft) MSL. An exception is a range of hills that reach elevations of 400 to 420 m (1,312 to 1,378 ft) along the west shore of the Volga River.

2.3 Area II Topography. Area II is primarily mountainous. Numerous ranges, often perpendicular to each other, stretch across the entire area. The only large plain in area II is formed by the Danube River valley, which runs through Hungary, northeastern Yugoslavia, and Bulgaria. Another smaller plain lies in Italy's Po River valley. Elevations are generally less than 300 m (984 ft) and the terrain is relatively flat. There are eight major mountain ranges in Area II.

- The Apennine Mountains form the "spine" of Italy, with a maximum height of 2,930 m (9,613 ft) northeast of Rome. These mountains start in southern Italy and run northwest to the Po River.

- The Alps run south to north along the southeastern French and northwestern Italian borders, turn eastward along the northern Italian border, and continue east into Austria. The highest ranges in the Swiss and Austrian Alps, generally oriented west to east, average from 2,440 to 3,350 m (8,005 to 10,991 ft). The highest elevation is more than 3,660 m (12,008 ft) just south of Innsbruck, Austria.

- Several mountain ranges run along the western Czechoslovakian border. These include the Sudetes and Ore Mountains on the north and northwest and the Bohemian Forest on the southwest. The mountainous spine formed by these ranges extends into Germany. The German extension of this feature is the Jura Mountain range that runs parallel to and just north of the Danube River. Elevations average from 200 m to 1,000 m (656 ft to 3,280 ft). The highest elevations in these ranges are: The Sudetes, 1,603 m (5,258 ft); the Ore Mountains, 1,244 m (4,080 ft); and the Bohemian Forest, 1,456 m (4,776 ft).

- Another series of ranges runs north-to-south on both sides of the Rhine River northward from the Alps. The Vosges and Eifel mountains are on the west, with the Harz mountains and Thurington Forest on the east. Elevations average from 200 to 1,000 m (656 to 3,280 ft). The highest elevation in the Vosges is 1,425 m (4,674 ft); in the Harz, 1,142 m (3,746 ft); and in the Thurington Forest, 982 m (3221 ft).

- The Carpathian Mountains form a crescent that extends eastward from central Czechoslovakia through the Ukraine, then southward into east central Romania. A secondary range, the Transylvanian Alps, is considered a continuation of the Carpathians. It extends east to west across central Romania. The Carpathian Occidental range runs southwest to northeast from southwestern Romania along western Romania. Heights in all three ranges vary greatly, reaching a maximum of 2,040 m (6,693 ft) in eastern Czechoslovakia at 48°55' N, 19°40' E. Elevations in Czechoslovakia average 920 to 1,520 m (3,018 to 4,989 ft). Along the eastern portion of the Carpathians in Romania, elevations average 1,420 to 2,100 m (4,659 to 6,890 ft). The highest elevation is 2,560 m (8,390 ft) at 45°30' N, 24°30' E. The Danube River cuts across extreme southwestern Romania at the intersection of the Transylvanian Alps and the Carpathian Occidental Mountains in a deep and narrow gorge called "The Iron Gate." Under the right meteorological conditions, this gorge acts as a "venturi" to increase downstream wind speeds dramatically.

- The Balkan Mountains run east to west south of the Danube River in Bulgaria. Heights average 2,130 to 2,740 m (6,988 to 8,989 ft), with a maximum height of 2,930 m (9,613 ft) at 42° N, 24° E..

- The Dolomite Alps run from northeast of the Po Valley to a point north of the Adriatic Sea where they merge with the Dinaric Alps. These Alps run southeastward along the Adriatic Sea coast of Yugoslavia, Albania, and into northern Greece. Elevations run from 1,520 to 2,440 m (4,087 to 8,005 ft). The highest elevation is 2,930 m (9,612 ft) in extreme northern Greece at 40° N, 22° E.

- Mountains in the Caucasus Range, oriented WNW to ESE between the Black and Caspian Seas, are the highest in Europe with very rugged relief. The Rioni and Kura River valleys run WNW to ESE 97 to 130 km (60 to 81 mi) north of the Turkish border. The bases of these valleys range in elevation from 300 to 900 m (981 to 2,953 ft) and are from 5 to 100 km (3 to 62 mi) wide. Ranges on either side of the valleys average 2,740 to 4,270 m (8,989 to 14,009 ft) in elevation. The highest peak in Europe, (5,633 m, 18,481 ft) is Mount Elbrus at Gora El Bruns in Russia, 43°20' N, 42°30' E. The Ay-Petrinishaya Yayala range extends west from the Caucasus along the southern shore of the Crimean Peninsula, and averages 910 to 1,220 m (2,986 to 4,003 ft) in height. The Kuzey Avadollu Dagari range extends westward from the Caucasus along the southern coast of the Black Sea in northern Turkey. It averages 1,520 to 2,130 m (4,987 to 6,988 ft) with a maximum height of 3,920 m (12,861 ft) at 41°10' N, 40°50' E.

CHAPTER 3

AN INTRODUCTION TO LOW-LEVEL WIND SYSTEMS

3.1 **Atmospheric Forces.** Atmospheric motion results from the interaction of several forces driving the air flow according to the Laws of Thermodynamics. The basic interactive forces that cause these motions are gravity, hydrostatic pressure, friction, and coriolis deflection. Another force similar to friction, but of such magnitude as to warrant separate consideration, is that caused by a barrier or obstruction, such as a hill or mountain.

3.2 **Antitriptic Winds.** Most locally-identified winds discussed in this report are in a general class called "antitriptic." An antitriptic wind occurs when friction exerts about the same force as the pressure gradient and when Coriolis and acceleration factors may be neglected. Antitriptic winds blow in the general direction of the pressure gradient. Land and sea breezes and mountain or valley winds are examples. Although jet (or "venturi") effect winds are considered to be antitriptic, convergence of streamlines between obstructions to flow is the dominant factor in their motion. Two other antitriptic winds are the "foehn" and the "bora," both driven in the vertical by gravity and the pressure gradient. Synoptic scale systems may modify and intensify antitriptic winds.

3.3 **Pressure Gradient Winds.** Some locally-identified winds are the result of very tight pressure gradients in a synoptic scale pressure system. Frequent observance of winds with identifiable characteristics in the same geographical area has given them special, descriptive local names. As previously noted, synoptic systems frequently play a significant role in the intensity of antitriptic winds.

CHAPTER 4

GENERAL CHARACTERISTICS OF LOW-LEVEL WIND SYSTEMS

4.1. Land and Sea Breezes. Land and sea breezes are induced by temperature and pressure differences resulting from differential heating of the air over adjoining land and sea surfaces. The prerequisites for a classic land or sea breeze are clear skies and a weak synoptic scale pressure gradient. In the ideal case, the sea breeze develops 3 to 4 hours after sunrise and reaches maximum intensity during early afternoon, diminishing during late afternoon and evening. The land breeze begins during late evening and continues through the night, ending in mid-morning. The frequency of these systems' occurrence generally decreases with increasing latitude. In Mediterranean regions, they develop on 31, 82, 91 and 35 percent of days during spring, early June, July, and autumn, respectively. At higher latitudes, such as in the Baltic area, they develop only on 20 percent of days, even in summer. Table 1 gives the probability of sea breeze occurrence for different amounts of cloudiness along the Black Sea.

TABLE 1. Relationship Between Cloudiness and Sea Breeze Probability Along the Black Sea (after Defant 1951).

Cloudiness......................	CLR-5/10	6/10-8/10	9/10-10/10
Probability of sea breeze, day......	90%	39%	27%

The thickness of the sea breeze layer varies with climate and local conditions. Around small lakes, the top of the sea breeze layer reaches about 150 m (492 ft). Around larger lakes, thickness varies from 200 to 500 m (656 to 1,640 ft), but generally remains below 1,000 m (3,281 ft) even along sea coasts. The thickness of a circulation system generally decreases with increasing latitude. The speed of the sea breeze is irregular and gusty, usually averaging 3 to 5 m/s (6 to 10 kts), with gusts to 13 m/s (25 kts). Sea breeze winds normally extend 15 to 50 km (9 to 31 mi) inland. Land breeze speeds are normally less than 3 m/s (6 kts) (Defant 1951).

4.2 Mountain and Valley Winds. Mountain and valley winds have two main causes: As air over mountain and valley slopes is heated during the day it rises; during radiational cooling of air along the slopes at night, it sinks. Clear skies are ideal for the development of mountain-valley wind systems. The best-developed examples of these systems occur when a valley is surrounded by mountains. Under these conditions, an upslope or valley wind blows upvalley from 0900 or 1000 LST until sunset. A downslope or mountain wind develops after sunset and continues until shortly after sunrise. The valley wind typically extends vertically to between 1 and 2 km (3,281 to 6,562 ft) from the valley floor. Maximum speeds occur between 200 to 400 m (656 to 1,312 ft) above the valley floor. The upslope flow normally arches from the valley several hundred meters above the ridge crest. More stable mountain winds are confined to lower levels. Valley wind speeds are normally 5 to 6 m/s (10 to 12 kts) (Defant 1951).

4.3 Orographically Modified Winds and Associated Phenomena.

4.3.1 Foehn/Bora Winds. The effects of terrain on atmospheric flow are very significant. Air flow over an obstacle assumes a wave shape. Air rising on the windward side of a ridge (orographic lift) results in the thickening and lowering of clouds and an increase in intensity and duration of precipitation. Flow down the leeward side causes a decrease in thickness or dissipation of clouds, as well as a diminution or cessation of precipitation. The extreme dryness of the descending air provides negative buoyancy that varies in degree depending on whether the descending air is warmer (as in a foehn wind) or cooler (as in a bora wind) than its environment. With a strong pressure gradient driving the air across the ridge, foehn and bora winds occasionally reach hurricane force. Most frequently it is a bora wind that produces extreme windspeeds. The outstanding characteristic of the bora is its extraordinary violence, often causing heavy damage. There are calms between violent gusts of 50 to 60 m/s (97 to 117 kts). Atmospheric pressure fluctuations of 4 mm (5.33 mb) of mercury are not unusual. Boras frequently show diurnal variations in occurrence and intensity. The maximum for both occurs near sunrise. Weakest intensity is at midnight, with minimum occurrence in early afternoon (Defant 1951).

4.3.2 Mountain Waves. The most pronounced effect of orographic lifting is seen in polar air following the passage of a cyclone. The initial lifting, produced by the passage of air over a ridge, causes cumulus and cumulonimbus clouds to form on the windward side of the ridge and along the ridge crest. The mountain wave extends much higher than the ridge crests themselves, and induces clouds at correspondingly greater heights. The mountain wave effect extends to about 10 times the height of the ridge, with the upper limit normally at the tropopause. In strong situations, however, the tropopause may be penetrated or displaced upwards. Downwind flow is usually perturbed for about 50 times the height of the range. The intensity of mountain wave effects varies with the exposure of the ridge line to the direction of general air flow. The greatest effect with respect to both intensity and area is produced when the flow strikes a mountain ridge normal to the major axis (Flohn 1942).

Berenger (1958) describes his measurements this way: "The standing wave or mountain wave is a strong vertical motion of air that is many times identified by the clouds associated with the oscillations of the atmosphere. The severe turbulence associated with this air flow was determined by measurements in these standing eddies. These measurements were made downwind from Montage de Fure in France at 1,400 m (4,593 ft) above the surrounding terrain. Strong wind speed variations ranging from 10 to 25 m/s (19 to 49 kts) in the horizontal and from +8 to -5 m/s (+26 to -16 ft/s) in the vertical were observed in a time period of 2 or 3 seconds. This is equivalent to a vertical acceleration of 2 to 4 g."

One of the greatest hazards to flight in orographically-induced standing waves is the violent turbulence in the rotor cloud. If heading upwind, an aircraft can be caught in descending currents downstream from the rotor and be forced into the rotor cloud turbulence (Kuttner 1953).

An aircraft flying with the air flow (downwind) over the ridge line will normally be caught in the updraft and carried above the mountain top. This frequently forces the aircraft into the fully developed portion of the mountain wave where turbulence is strong enough to tear it apart.

Mountain waves can induce large barometric instrument errors. The results of studies to determine effects on pressure measurements inside the strong wind flow over mountain barriers indicate a pressure reduction proportional to the square of the wind speed. One such study showed that for a wind speed of 45 m/s (87 kts), the altimeter reading was 110 m (361 ft) too high for unsaturated air and nearly double that for saturated air (Alaka 1958).

An aircraft flying parallel to a long ridge that lies perpendicular to the wind under wave conditions could be subjected to horizontal wind speeds substantially different from those prevailing a few kilometers away. Any change in general wind speed will cause a sharp change in the wavelength and in the location of positive and/or negative vertical currents.

Vertical wind speeds in orographic standing waves may be intensified if there is a succession of ridges spaced to match the harmonic of the airstream's natural wavelength. For example, if the second, third, and fourth ridge lines are positioned correctly, they can add energy to the mountain waves and produce stronger vertical currents.

Mountain waves form more easily when lee slopes have a precipitous drop rather than a smooth and gentle gradient. To determine the winds associated with optimum wave conditions in a particular locale requires careful observation over a long period. The most frequent and severe turbulence forms in the standing eddies under the wave crests at ridge-top level.

Aircraft icing in a mountain wave depends largely on the concentration of supercooled liquid water in the cloud. Clouds formed by their ascent over mountains have a much greater liquid content than clouds formed in free air. If conditions are generally favorable for icing, expect a greater probability or intensity over and immediately upstream of the ridge crest.

Alaka (1958) identified several conditions that must exist simultaneously for mountain wave formation. They are:

- Marked stability in lower layers with comparatively low stability aloft. Stable layers need not necessarily reach the ground.

- Wind speed at the ridge crest level must exceed a critical minimum that ranges from 8 to 13 m/s (15 to 25 kts). The range depends on ridge orientation relative to wind direction and ridge configuration. These winds must either increase or remain constant up to a height of at least 1.5 times the ridge crest height (rotor streaming) or up to the tropopause (wave streaming). Wind direction must be within 30 degrees of perpendicular to the ridge crest and not change substantially with altitude.

Another investigator (Forchtgott, 1949), found that mountain wave formation depends on the vertical windspeed profile (dotted vertical curve) as shown at the left of each diagram in Figures 1 through 5. Forchtgott divides mountain waves into the four basic classifications (laminar streaming, standing eddy streaming, wave streaming, and rotor streaming) shown in Figures 1 through 5.

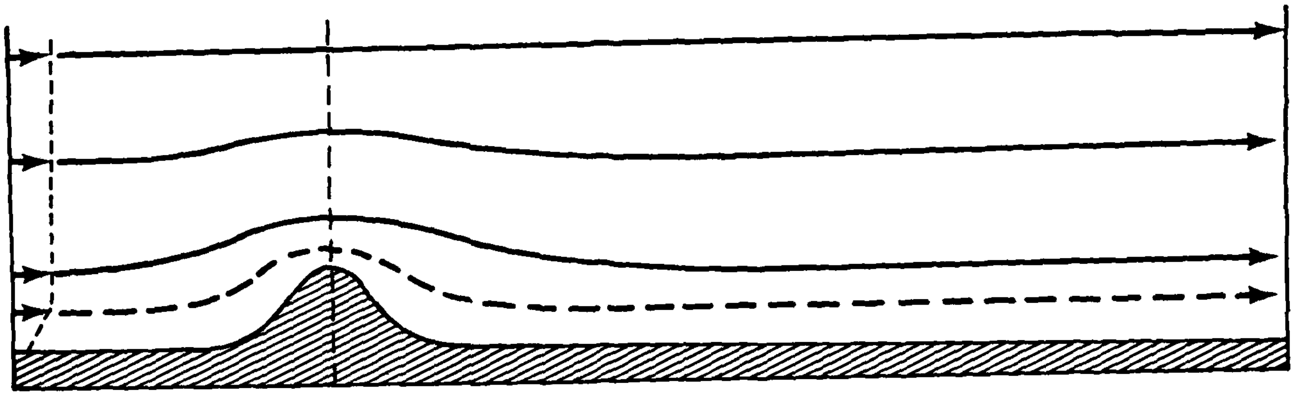


Figure 1. Airflow Over Ridges: Laminar Streaming. According to Forchtgott, "laminar streaming" occurs with light winds. Airflow near the surface follows ridge contours. Wave amplitude decreases rapidly with height. No waves occur downstream of the ridge; the only wave occurs over the ridge crest.

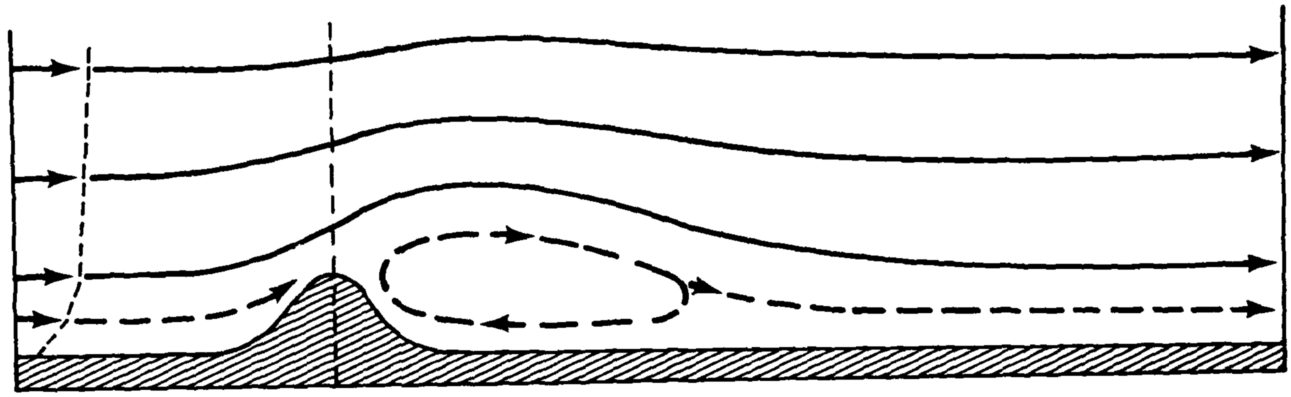


Figure 2. Airflow Over Ridges: Standing Eddy Streaming. As shown here, "standing eddy streaming" results in slightly stronger winds than with laminar streaming. A standing eddy forms on the lee side of the ridge; maximum vertical airflow displacement is downwind from the crest.

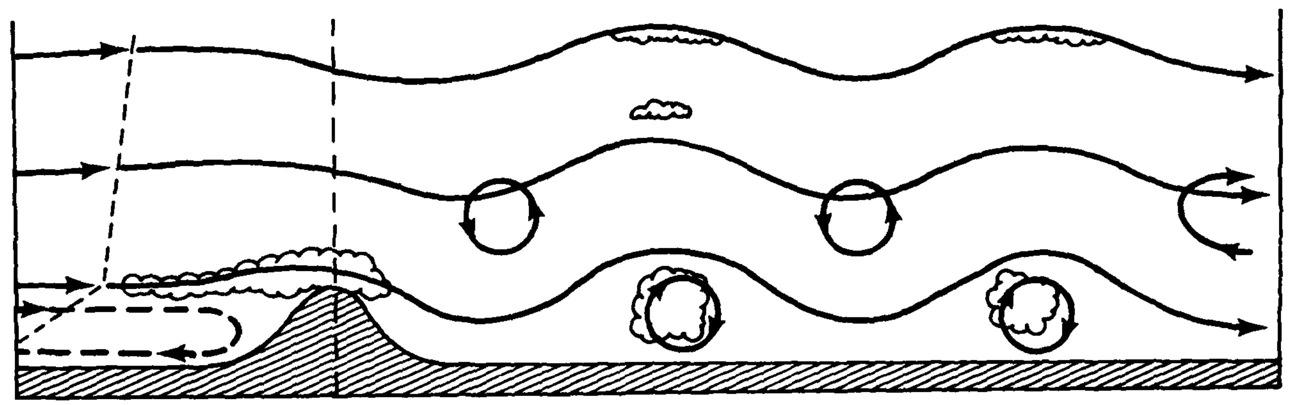


Figure 3. Airflow Over Ridges: Wave Streaming. The "wave streaming" shown here is stronger than with "standing eddy streaming," and occurs when windspeeds increase with height. If the air is moist enough, lenticular clouds form at each wave crest. Rotors form at low levels under each wave crest. If clouds form, they will be ragged and seem to rotate. Multiple waves will form downstream of the ridge crest. In the absence of additional ridges, the greatest amplitude occurs with the first wave. There is always turbulence.

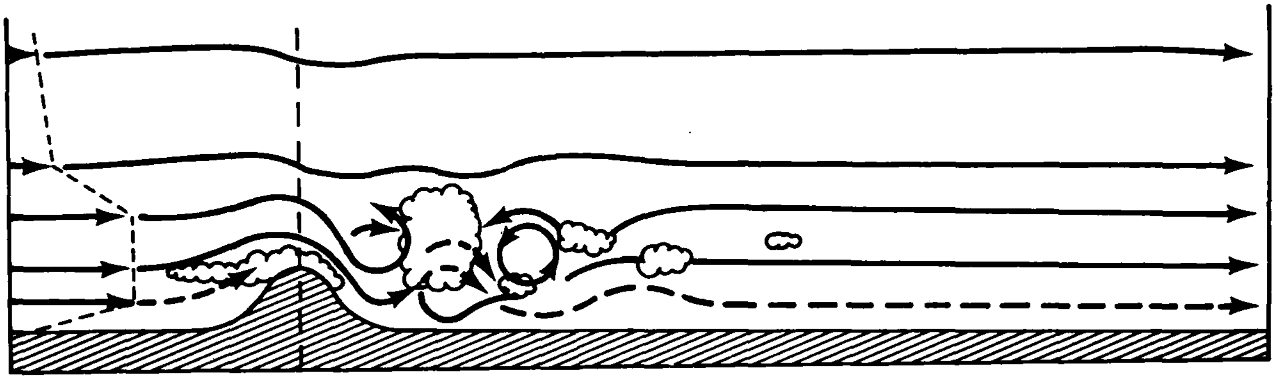


Figure 4. **Airflow Over Ridges: Rotor Streaming With Mid-Level Inversion.** The "rotor streaming" shown in this figure requires a very strong windspeed core rising to a height not exceeding 1.5 times the crest height. Speeds above this core decrease rapidly to fairly weak values, and remain weak up to the tropopause. The rapid decrease is caused by a temperature inversion at the top of the wind speed core. This situation produces vortices on either side of, and under, the downstream low-level wave crest. These vortices rotate in opposite directions. As a result, severe to extreme turbulence is found in the immediate vicinity.

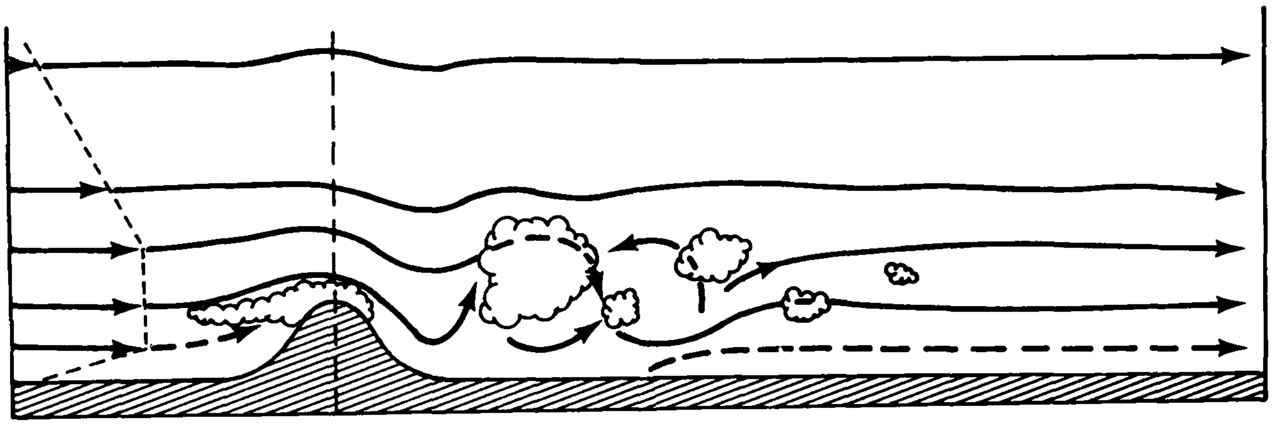


Figure 5. **Airflow Over Ridges: Rotor Streaming With No Mid-Level Inversion.** This rotor streaming example also requires a very strong wind speed core rising to a height not exceeding 1.5 times the crest height. Unlike the example in Figure 4, however, wind speeds above the core diminish gradually to relatively weak values at the tropopause. The mid-level inversion found in Figure 4 is absent. A contrarotating vortex couplet forms at and just downstream of the low-level wave crest. Severe turbulence is found on the upwind side of the couplet and over the couplet intersection.

4.3.3 **Jet Effect Winds.** A pressure gradient normal to an orographic constriction will drive air through an opening in that constriction. The result is a significant increase in wind speed on the downwind side of the constriction. This phenomenon, also called the "venturi," "funnel," "channeling," or "cornering" effect, normally occurs in combination with any of the preceding winds to act as an intensifier.

CHAPTER 5

LOCAL WINDS IN AREA I

5.1. **Land and Sea Breeze Winds.** These winds occur infrequently along the coastal regions of northern Europe. Even during summer, the season for maximum occurrence, they are rarely observed on more than 20 percent of the days. Under neutral synoptic wind conditions, mean wind speeds seldom exceed 5 m/s (10 kts), and gusts seldom exceed 10 m/s (19 kts). These winds rarely extend to more than 24 km (15 mi) inland.

During weak but discernible synoptic patterns, winds along the Polish coast of the Baltic Sea penetrate different distances inland depending upon the general flow pattern. In May and June, mean wind speeds are generally 2 to 3 m/s (4 to 6 kts). With a westerly flow, inland penetration can reach up to 70 km (44 mi). With southerly flow, penetration is limited to 10 km (6 mi). The sea breeze follows the normal time cycle with westerly and easterly flow patterns. Compared to the normal cycle, however, the sea breeze cycle starts several hours earlier with northerly synoptic flow and several hours later with southerly synoptic flow (Michalezewski 1965).

The winds on Lake Seven in central Russia typify winds to be expected on a small lake in July. The lake breeze occurs a few times during the month, generally reaching 150 to 200 m (492 to 656 ft) in height. The mean speed is 1 to 2 m/s (2 to 4 kts) and occurs from 1000 to 2000 LST. The upper level return flow may reach 500 to 600 m (1,640 to 1,968 ft) (Vorontsov n.d.).

The winds on northwestern Russia's Lake Ladoga in July and August can be used as an example of winds on a large lake. Lake breezes occur on an average of 35 percent of days. They extend from 200 m to 900 m (656 to 2,953 ft) above the lake's surface. Maximum wind speeds occur at a height of from 1/5 to 1/6 the maximum altitude. Mean value of the maximum speed is generally less than 5 m/s (10 kts). There are two types of lake breeze circulation:

- The first develops gradually as on-shore flow in the early morning. When a high pressure center is over or just south of the lake, the breeze generally begins at about 0700 LST, extending to a height of 200 m (656 ft).

- The second is associated with an intrusion of cold air similar to a cold front, but in miniature. The high pressure ridge is more distant, and the capping effect is not as strong. This miniature cold front develops when there has been enough heating of the air over the land to develop on-shore air flow. This heating generally develops at about 1200 LST. The air flow extends to a height of 800 to 900 m (2,624 to 2,953 ft). When local and synoptic pressure patterns coincide, the winds start earlier than usual. But if the local and synoptic pressure patterns are in opposition, they start later than normal (Vorontsov 1958).

5.2 **Mountain and Valley Winds.** These are limited to the very few regions in Area I where there are orographic features of any consequence. In the northernmost part of Finland, where there are some such mountains and valleys, these winds are observed occasionally. Valley winds are usually the stronger of the two, although both are very slight (1 to 4 m/s or 2 to 8 kts) and occur mostly during the summer when effects of solar heating are greatest.

5.3 **Foehn Winds (Sukhovei).** Because of the limited number of orographic features in Area 1, occurrence of foehn winds is infrequent and limited to the few regions with mountains, such as northern Finland. But a related wind, similar to the "free foehn" of the Alpine regions, is the Sukhovei of southeastern European Russia. The Sukhovei is a hot, dry, and dusty easterly or southeasterly wind that occurs over Ciscaucasia in summer. It develops with the formation of a warm upper-level anticyclone producing very dry subsiding air aloft over the region. Although the subsiding air never actually reaches the surface, it contributes to the winds and the extremely turbulent mixing associated with the cloudless skies that assure maximum solar heating and convection. Dust from the Sukhovei may be lifted 1 to 2 km (3,281 to 6,562 ft) to reduce visibility significantly. When prolonged, the Sukhovei is very damaging to agriculture. Eastern Ciscaucasia experiences more dry winds than western Ciscaucasia. The protection afforded by the Stravropol 'skaya Vozvyxhennost' and the more humid conditions adjacent to the Black Sea and the Sea of Azov cause a sharp drop in the number of days with dry winds in the western section of Area I. The strongest Sukhovei winds are associated with the tightest pressure gradients along the southern outskirts of a high pressure ridge moving to the southeast across or immediately to the north of the area. These highs move very slowly. They frequently become stationary and result in long periods of dry winds and drought. Maximum occurrence is in May, July, and August. The average number of days with dry winds (April through September) for selected stations in affected regions is given in Table 2.

TABLE 2. Average Number of Days with Dry Sukhovei Winds at Selected Stations in European Russia.

Station		Apr	May	Jun	Jul	Aug	Sep	Total
Rostov	(47° N 40° E)	2	5	2	4	6	2	21
Tikhortsk	(46° N 40° E)	3	5	1	4	5	1	19
Armavir	(45° N 41° E)	4	5	2	4	4	2	21
Divnoye	(46° N 43° E)	3	8	7	12	9	4	43
Prikumsk	(45° N 44° E)	3	6	6	8	6	3	32

Afternoon temperatures during these dry winds average 3° to 6° C (5° to 10° F) warmer than normal. Relative humidity is low, frequently 10 or 15 percent. Cloudiness is at minimum. High wind speeds contribute to the drying effect. In May, durations of these dry winds have reached 29 days at Divnoye and 26 days at Prikumsk (NIS USSR 1962, Yevseyev 1958).

5.4 **Bora Winds (Novaya Zemlya).** Only a few regions in Area I have mountains with the elevation and orientation necessary for development of bora winds. One of these regions is on the island of Novaya Zemlya off the Arctic coast of European Russia. Novaya Zemlya has a rib of mountains that extend the length of the island and descend to the sea, an ideal configuration for a gravity-type wind such as the bora, which occurs with great force and gustiness on the eastern and western coasts. The Novaya Zemlya bora occurs frequently in winter, but rarely in summer. Average duration is about 24 hours, but it can continue for much longer periods. In December 1898, a bora at Malye Karmakuly (72° N, 56° E) with a mean speed of 37 m/s (72 kts) raged for 5 days. The air temperature at the time was -31° C (-24° F). Weather stations on Novaya Zemlya often record speeds of 30 to 40 m/s (58 to 78 kts). The wind recorder at Matochkin Shar (74° N 57° E) has registered a mean hourly speed of 47 m/s (91 kts). Gusts in Novaya Zemlya boras attain remarkable force (60 m/s (117 kts) or more). In the summer of 1932 at Matochkin Shar, a strong gust forced a hydroplane flying at 1,000 m (3,281 ft) into the sea where it crashed. Although the bora does not extend very far out to sea, it can be felt at distances of 15 to 20 km (9 to 13 mi) offshore.

The arrival time of the Novaya Zemlya bora can be predicted fairly accurately from certain local indicators. The following are most important:

- An offshore wind starts to blow gustily about 12 hours before the beginning of the storm. Small cumulus clouds form over coastal mountains and ravines about 6 to 10 hours before onset. Simultaneously, there is a decrease in general cloudiness. Later, general cloudiness increases rapidly while the wind increases and the barometer falls slowly seldom more than 0.5 mm an hour. There have been a few instances in which the bora began with a pressure rise (pressure indications here are based on instances of boras on the west coast).

- Relative humidity falls noticeably about 6 to 10 hours before the storm begins. The average speed of the offshore wind at the time of the relative humidity minimum varies from 7 to 12 m/s (14 to 23 kts).

- Although each of the above indicators are identified as warnings by Prib (1946), any single one, occurring alone, is not enough for a reliable prediction. The combined occurrence of these indicators can provide a reasonably reliable 6- to 8-hour warning before the bora begins.

5.5 **Jet Effect Winds.** These winds rarely occur in Area I proper because of its lack of significant orographic features. Regions where they can occur are in northern Finland and on Novaya Zemlya Island. Some channeling of winds can occur, however, where ridges or river valleys extend to the coasts of northern and central Europe.

5.6 **Synoptic Scale Pressure Gradient Winds.** Most of the high winds observed over the central plains of Europe are associated with synoptic scale pressure gradients. This is especially evident along the north-central European coasts since a frequently-followed low pressure system track runs through the Baltic Sea. These systems can cause gale force winds along Baltic coastal areas.

CHAPTER 6

LOCAL WINDS IN AREA II

6.1 **Land and Sea Breeze Winds.** Along the coastal regions of Italy, land and sea breezes occur from April through September or October. The breeze direction is determined by the shape of the coastline. Many hilly areas on the Italian peninsula experience on-shore flow guided by terrain through the valleys. Land breezes are guided the same way. The sea breeze usually begins between 1000 and 1200 LST and ends after dusk. Depth of circulation is between 150 and 610 m (493 and 2,001 ft), with afternoon breezes of 4 to 7 m/s (8 to 14 kts). The land breeze starts anytime after dusk, with an average speed of 5 m/s (10 kts), and blows until shortly after dawn.

Venice experiences a local daytime sea breeze that brings south-southeasterly flow inland until about midnight. Nocturnal flow is more complex due to unequal cooling by the Alps and the adjacent low-lying regions that extend to the Adriatic Sea (Camuffo 1979). Since the Adriatic Sea experiences less diurnal temperature variations than the adjacent land, a pressure gradient is induced as the night progresses. The night flow is from the northeast, with circulation depth to about 500 m (1,640 ft) and a maximum speed of 6 m/s (12 kts) (Camuffo 1979). The intensity and direction of the land breeze at Venice may be affected by nocturnal mountain winds that flow parallel to the Alps and the Adriatic Sea coastline.

Coastal Yugoslavia experiences these summer breezes, too. The sea breeze is stronger than the land breeze, and sometimes reaches speeds of 11 m/s (21 kts). The sea breeze starts before noon and continues until sunset, when the land breeze sets in and continues until about sunrise.

Land and sea breezes are also common along the coast of Albania. They are especially prevalent in summer because of significant diurnal temperature changes. They usually start about 1000 LST and increase steadily until reaching maximum strength in the afternoon, then die at about sunset. Albanian sea breezes penetrate far inland when reinforced by the general circulation. Land breezes begin in the late evening and taper off near sunrise. The land breeze is the weaker of the two. (NIS Albania 1963).

Land and sea breezes occur anytime between May and October for the island and coastal areas of Greece. Sea breezes normally start about 1000 LST, reach full strength in the afternoon, and die about sunset. Sea breezes normally penetrate inland about 16 km (10 mi), but occasionally reach 40 km (25 mi). Greek land breezes start about 2300 LST and end by early morning. Greek sea breezes are not always distinguishable from Etesian winds (See para 6.6.3), since they may come from the same northerly direction (NIS Greece 1961). A different phenomenon, however, occurs in the Gulf of Athens. It is not unusual for the sea breeze to override the northerly etesian flow in Athens. The region east of a line from Sunion, near Athens, to the island of Hydra, off the coast of Peloponnesus in southern Greece, presents a different problem. Here, a southerly sea breeze will flow into the Gulf of Athens while the northerly etesian continues to flow over Peloponnesus (der Lan n.d.).

Winds along the Black Sea coasts of Romania and Bulgaria show definite diurnal variations from March through October. Romania and Bulgaria both get afternoon sea breezes along their Black Sea coasts. The Romanian coast normally gets a land breeze late at night and in early morning, while conditions on the Bulgarian coast are often calm.

Land and sea breezes along the southern coast of the Crimea occur 45 to 54 percent of the time. The onset of the sea breeze is normally 0700 to 1000 LST, except for the winter season, when 1100 to 1200 LST is more typical. Where the mountain barrier descends almost to the sea, such as at Sanych Beacon, Simeiz, and Alapha, the sea breeze is greatly inhibited. Cities in valleys, such as Yalta, Alushta, and Sidak, experience a sea breeze on more than the normal number of days. The sea breeze reaches its greatest frequency during the warmer half of the year, occurring more than 60 percent of days at locations like Yalta. Generally, the winds have a westerly component in spring and summer, and an easterly component in fall and winter.

In general, land and lake breeze systems are so poorly developed and weak in the vicinity of landlocked lakes that little attention will be paid them here. An exception is the circulation system associated with Lake Balaton in western Hungary, which is sufficiently well developed to be worth mentioning. This system is an example of the maximum circulation development that can be expected near an inland lake. In summer, the Lake Balaton wind system develops on 22 percent of days in daytime and 15 percent of days at night. Daytime lake breezes penetrate inland 5 and 10 km (3 and 6 mi) 60 and 12 percent of the time, respectively. The lake breeze generally starts between 0700 and 0800 LST and stops between 1700 to 2000 LST. In the daytime, the lake breeze extends to a height of about 300 m (960 ft), while under ideal conditions, the return flow may extend to a height of 2,000 m (6,560 ft). The land breeze is significantly weaker than the lake breeze, with values generally one-half those of the latter (Gyorgy 1962).

6.2. Mountain and Valley Winds. The phenomenon of the daily wind change along the axis of large valleys occurs in all the mountainous countries of Area II. From about 0900 or 1000 LST until sunset, there is an upvalley (or valley) wind. At night, an opposite downvalley (or mountain) wind appears and continues until shortly after sunrise. There have been numerous investigations of this phenomenon, including vertical soundings, in many mountainous countries (Putnick 1943).

Mountain and valley winds are best developed in the wide and deep valleys of the Alps. In fairly level valleys, such as the valley of the Inn River in Tirol, they are particularly well developed. They occur most frequently during persistent high pressure situations and are typical fair weather summer phenomena. When mountain and valley winds occur on cloudy days or in winter, they are manifested mostly as modifications of the general wind.

Strong mountain or valley breezes occur near the northern border of the Po Valley even though winds in the Po Valley are typically calm. Many wind roses for sites in the Po Valley area show the two longitudinal wind directions consistent with those expected in a mountain-valley circulation. The western part of the Po Valley, or Piemonte, looks like a basin. The valley breeze directions from the Po Valley tend to form a fan, opening toward the surrounding Alps (Gandino 1976). Venice experiences a type of mountain wind moderated by the Adriatic Sea. Venice's mountain wind is nocturnal, starting about midnight (Camuffo 1979).

Light mountain or valley winds occur in Albania, especially in the interior mountain region. Mountain or valley winds are common in the mountains of Yugoslavia. They are usually light and occur mainly in the summer (NIS Albania 1963, NIS Yugoslavia 1964).

Light and variable surface winds usually have a westerly component over Bulgaria and most of Romania. The upper level winds also have a westerly component. In northwestern Romania and northeastern Hungary, there is unobstructed development of the mountain-valley wind system. This circulation manifests itself from 15 to 20 days a year in the eastern Hungarian lowlands east of the river Tiszan to the mountains of the Transylvania Alps. The valley wind dominates from 0900 to 1900 LST, while nocturnal mountain winds are observed between 1900 and 0900 LST (Gyorgy 1963). Mountain and valley circulation also occurs in northeastern Hungary (because of the Carpathian Mountains) and in the mountains surrounding Hungary (NIS Hungary 1964). Budapest experiences a local wind system that results in air flow toward the interior of the city. This flow occurs at night, with the greatest frequency from 2000 to 2200 LST. This metropolitan wind system usually occurs every third day except in September and October, when it can be expected every second day. This system influences surface winds up to 1,000 m (3,280 ft), with a maximum intensity between 500 and 600 m (1,640 and 1,968 ft) (Gyorgy 1962, 1963, Stanchev 1974).

In the Ukrainian Carpathians, mountain-valley winds are better developed in summer than in winter. At Tyachevo, USSR, the summer mountain-valley winds occur on two-thirds of the days. These winds are almost independent of slope exposure, but are affected significantly by valley configuration. As usual, mountain-valley winds are more pronounced in wide valleys with gentle slopes. During the summer, mountain winds may not occur at night, but valley winds are well developed during the day. Mountain-valley wind speeds are on the order of 2 to 3 m/s (4 to 6 kts) (Tokmakov n.d.).

6.2.1 Maloja Wind. The Maloja wind is named after the windshed between Engadine and Bergell, Switzerland, where it appears to be particularly well developed. The Maloja is a mountain wind that blows downvalley both day and night. It is caused when the valley wind from one valley reaches over a pass into another valley. How the Maloja develops is primarily determined by which one of the valleys involved has the larger diurnal temperature amplitude and can thereby extend its circulation across the pass and into the other valley. The question of whether this phenomenon can be completely explained by the further increase of diurnal temperature variation beyond the pass, or whether it is purely an inertial extension of the more strongly developed valley wind, has not been answered satisfactorily. Sometimes, as has been shown at the Arlberg Pass in Tirol, Austria, a strong upslope wind in one valley can, after crossing a pass, augment a valley wind in another valley (Ekhart 1931).

Even in the absence of a mountain pass, the interplay between thermal slope winds and typical mountain or valley winds sometimes produces anomalies in the latter. Wind shifts in a valley wind system are caused by stronger insolation on one slope than the other. There are cyclic wind shifts in the course of a day because the upslope wind starts before the valley wind and the downslope wind starts before the mountain wind.

6.2.2 Liptowski Wind. The Liptowski winds are westerly or southwesterly winds that flow through the Morskie Oho depression into the Sucha Voda Valley of southeastern Poland. They start about noon on good weather days. This shows they are not mountain winds. In fact, they block the valley winds that normally blow at this hour of the day. The Liptowski develops much like the upper Engadine wind (the Maloja). It results from a difference in heating rates between the southern valley, including the Liptowski Valley, and the northern valleys. Wind speeds usually reach 6 to 8 m/s (12 to 16 kts), and occasionally reach 10 to 15 m/s (19 to 29 kts). The Liptowski winds differ from "halny" winds because of their high humidities. They may penetrate as far as Pajakowce. They occur more frequently in spring, late summer, and autumn than in other seasons. (Martyn 1977).

6.3 **Foehn Winds.** The foehn wind is probably the greatest flight hazard in Area II. Clouds formed by airflow on upslopes cause precipitation and icing. There is icing on the downslope side until the cloud either warms to above freezing or dissipates. The forced rise and rapid cooling of air results in a very coherent cloud formation covering the top of the ridge on the windward side and is called the "foehn wall." Foehn clouds frequently are very turbulent and may contain intense convective currents, especially during afternoon thunderstorms. Upslope convergence and downslope divergence strengthen high altitude winds over the mountain ridges and cause strong acceleration of air movements. Foerchtgott (n.d.) states that the mechanical turbulence of the wind increases in direct proportion to this acceleration. The higher the orographic obstacles, the greater the difference in weather between the windward and leeward sides. In the lower mountains, e.g., the Bohemian-Morovian Highland of western Czechoslavokia, the influence of the rise and descent in the airflow is expressed mostly by the lowering of cloud ceilings on the windward side of the mountain and eventually in the partial break-up of clouds on the leeward side. The frequency of the foehn depends on the strength or weakness of the general atmospheric circulation. On an average, foehn winds occur 30-40 days a year in the Alps (Lewinska 1958).

Numerous observations have shown that despite favorable atmospheric flow, foehn clouds may not always form, as when a "rebounded foehn" develops. The "rebounded foehn" results from distortion of high altitude winds over mountain ranges and is manifested by a warming effect on the windward side of the mountain. Clouds influenced by the warming trend usually scatter. The decrease in cloud cover above the mountains may be observed when an anticyclone, with strong descending currents, affects the region. In this case, it is possible to observe the foehn's warming effect from a cloud-free atmosphere on both slopes simultaneously.

Generally speaking, the speed of the foehn (or descending current) is greater than an ascending current. While average speeds of the foehn are usually not more than 10 to 13 m/s (20 to 25 kts), winds reaching gale forces of 15 to 21 m/s (30 to 40 kts) are not unusual. Very strong foehn conditions have produced hurricane force (33 m/s or 65 kts) winds. Because of the great heights from which foehns often blow, temperature and humidity changes can be large. As a result, widespread thawing of the snow cover can occur almost overnight in winter, causing floods and avalanches. Foehns occur during the cold half of the year with maximum frequency in late winter and spring. They may be observed anywhere along the periphery of mountains.

The foehn winds associated with the Bavarian Alps, oriented west to east, blow from the south across the mountains with low pressure to the west and high pressure to the east. Because of its origins, the warm air from the south is well suited to the development of a marked foehn phenomenon. The frequency of these winds, often called "prefrontal foehns," is directly proportional to the frequency of lows traveling eastward north of the Alps.

If low pressure is to the east and high pressure to the west, cold air is piled up on the north side of the mountain top. It then descends on the lee side while warming. The descending air shows foehn properties when the warming process causes it to arrive on the lee side of the mountain markedly warmer and drier than the air it replaced. This type of foehn is called the "north foehn" (Defanti 1951). From the view of an operational meteorologist, such foehns might also be termed "post frontal." In winter, air that reaches the base of the mountain is frequently colder than the air it displaced. This air flow constitutes the Tramantana wind (see paragraph 6.4.1).

"Anticyclonic foehns" occur in cloudless conditions since there is no air mass transport across the mountains; there is only descending air from a high over the Alps. Because a peak of the Eurasiatic pressure axis is located over the Alps in winter, anticyclonic foehns occur frequently during this season. With the small winter lapse rate, the thermal effect is pronounced. In the western Bavarian and Swiss Alps, there is a definite spring maximum, while in the eastern and southern sections of Germany, there is a definite winter maximum. Because of a shallow layer of cold air near the base of the mountain, the observed frequency generally increases with elevation. The phenomena can last 12 to 18 days, but those lasting longer than 6 days are rare. For a summary of longer foehn periods, see the following tables (Flohn 1942, Frey 1957).

TABLE 3. Frequency of Occurrence of Longer Foehn Periods in the Course of the Year in Germany. Period of Record 100 Years.

Minimum Duration,	Schneekoppe				Feldberg/Schw.				Brocken				Zugspitz			
days:	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
Jan	111	69	42	25	100	60	20	20	67	42	25	8	153	81	50	44
Feb	94	39	28	19	120	80	50	40	44	22	8	8	189	81	42	22
Mar	78	31	17	3	150	80	50	20	69	19	6	6	131	61	33	8
Apr	28	11	6	3	80	40	.	.	75	28	14	.	17	.	.	.
May	36	8	3	.	80	40	.	.	100	47	28	8	14	.	.	.
Jun	36	8	6	3	40	10	.	.	86	39	22	8	17	6	6	.
Jul	36	17	8	3	50	20	20	20	44	19	11	8	22	.	.	.
Aug	25	8	6	3	80	10	.	.	31	11	6	3	28	6	6	6
Sep	39	22	3	3	70	10	.	.	42	25	3	.	58	25	8	3
Oct	69	25	19	8	70	40	20	.	42	14	8	3	108	58	36	25
Nov	92	58	44	28	80	70	40	20	72	36	11	11	138	75	50	33
Dec	100	44	25	17	100	60	30	30	58	17	11	.	131	70	31	19
Year	744	310	206	114	1020	520	230	150	731	320	153	64	951	463	262	160

TABLE 4. Frequency of Occurrence of Longer Foehn Periods in the Seasons of the Year in Germany. Period of Record 100 years.

Length in Days: Summer (Apr-Sep)	2	3	4	5	6	7	8	9
Zugspitze	119	17	11	6	3	.	.	.
Schneekoppe	125	44	17	11	.	.	.	.
Feldberg Schw	270	110	.	.	20	.	.	.
Brocken	208	86	56	8	11	6	6	.

Length in Days: Winter (Oct-Mar)	2	3	4	5	6	7	8	9
Zugspitze	369	183	89	61	36	25	14	17
Schneekoppe	278	92	75	42	33	8	8	8
Feldberg/Schw	240	180	80	50	30	30	10	10
Brocken	203	81	33	17	6	.	6	6

TABLE 5. Seasonal Occurrence of Foehns: Altdorf, Switzerland, at Specified Hours, 1941-1954.

Hour Observed	Spring	Summer	Autumn	Winter	All Cases
0730	60	16	36	47	159
1330	100	26	65	67	258
2130	92	30	67	63	252
All Cases	252	72	168	177	669

Note: While the authors do not specifically indicate the months for each season, other material in their papers implies the following scheme: Winter, December-February; Spring, March-May; Summer, June-August; Autumn, September-November.

The foehn phenomenon occurs with fair frequency, and sometimes with great intensity, over the foothills of the Alps and the adjacent Po Plain. Foehns of long duration occur most frequently along the Piedmont slopes, where the greatest intensities have also been observed. Although the predominant foehn direction is northwest, it oscillates from west to east through north in the Po Valley. Ambrosetti (1976), in his study of winds in southern Switzerland, gives various wind speed occurrences and average number of foehn days for Locarno and Lugano. These stations can be taken as representative of north foehns blowing down over the southern Alpine slopes and approaching the upper Po Valley. See Tables 6 through 9 for samples of foehn frequencies at stations in northern Italy. Tables 7, 8, and 9 give the number of days with peak winds above the indicated speeds.

TABLE 6. Mean Number of Days with Northern Foehn in Upper Po Valley.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Locarno	5	6	7	7	4	4	3	4	2	3	4	4	53
Lugano	4	4	5	5	3	3	2	2	3	3	3	4	41

TABLE 7. Average Number of Days with Wind Speed Peaks Greater Than 11, 17, and 22 m/s (22, 33, and 44 kts) for Locarno Civil Airport, Switzerland, 1958-1974.

Speed Peaks Greater Than:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
11 m/s (22 kts)	2	3	5	6	5	3	3	4	2	2	2	2	39
17 m/s (33 kts)	.	.	1	1	1	1	1	1	.	.	.	.	6
22 m/s (44 kts)	0	.	.	.	.	.	.	.	0	0	.	.	2

Extreme peak recorded: 32 m/s (62 kts), 11 Dec 74, north foehn.

Note: Assuming that the author rounded to the nearest whole even number, the "0" values in the 22 m/s column were probably 0.5 to result in an annual value of 2.0.

TABLE 8. Average Number of Days with Wind Speed Peaks Greater Than 11, 17, and 22 m/s (22, 33, and 44 kts) for Locarno Military Airfield, Switzerland, 1940-1945.

Speed Peaks Greater Than:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
11 m/s (22 kts)	4	8	8	11	9	10	10	6	6	6	7	5	90
17 m/s (34 kts)	2	4	4	5	4	2	3	1	2	2	3	1	33
22 m/s (44 kts)	1	1	1	2	.	.	1	.	.	.	0	0	7

Extreme peak recorded: 31 m/s (61 kts), 25 Mar 44, north foehn.

TABLE 9. Average Number of Days with Wind Speed Peaks Greater Than 11, 17, and 22 m/s (22, 33, and 44 kts) for Lugano, Switzerland, 1967-1974.

Speed Peaks Greater Than:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
11 m/s (22 kts)	5	8	7	8	8	7	8	8	4	4	5	5	77
17 m/s (33 kts)	3	4	4	4	2	3	3	2	1	1	2	3	32
22 m/s (44 kts)	.	1	1	.	.	1	.	.	.	1	.	1	6

Extreme peak recorded: 34 m/s (66 kts), 4 Apr 67, north foehn.

Note: Most of the peak winds given in the preceding tables occurred in foehn conditions; all extreme peak north winds were in north foehns. Maximum foehn occurrence is in winter and spring at all three stations; most summer peaks are thunderstorm related.

Extensive wind data are also available from the EURATOM plant at Ispra, about 25 km (14 NM) SSW of Lugano. A study by Gandino and de Bortoli (n.d.) gives valuable supplemental information to that presented for Lugano. Once begun, foehn winds persist for an average of 9 hours; extreme cases have persisted for more than 60 hours. Cases of foehns occurring on 4 or more consecutive days are nearly all confined to winter and spring (Dec through Apr). Onset times closely parallel those given in Table 11 for Turin. Ending times show a marked maximum for 1200 through 1900 LST.

As might be expected, foehn conditions in the Po Valley are similar to those in the southern Alps. The western Po Valley has one of the highest incidence of Alpine foehn winds in Italy. Foehn frequencies for Turin, based on records for 1929 through 1944, are representative of this area. Bossolasco (1950) gives average monthly and annual number of Foehn days and hours for Turin in Table 10.

TABLE 10. Average Monthly and Annual Number of Foehn Days and Hours for Turin, Italy, 1929-1944.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Days	2.9	3.2	3.4	4.5	2.7	2.1	3.5	1.5	1.9	2.5	2.1	2.2	32.6
Hours	25	30	31	40	24	18	33	14	14	24	13	18	288

The maximum daily foehn occurrence is from January through May, or during winter and early spring. This is not surprising, since foehn occurrence is closely related to the formation of "Gulf of Genoa" low pressure areas. An interesting occurrence is the secondary daily maxima in July and October. According to Bossolasco (1950), a necessary condition for foehn occurrence over the Po Valley-Lombardy-Piedmont areas of Italy is the formation and eastward passage of either a "Gulf of Genoa" low pressure area or a secondary low along a frontal system passing through northern Italy. Bossolasco (1950) believes that the latter condition is responsible for the late spring and early fall maxima.

Of equal interest is the following frequency distribution of foehn onset times, again from Bossolasco (1950):

TABLE 11. Total Number of Foehn Wind Onset Times for Turin, Italy, 1929-1944.

Hour:	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Freq:	11	5	8	10	13	20	15	44	34	67	29	30	18	22	10	14	11	11	6	5	5	2	4	18

Note: Although favored onset times are between 0800 and 1200 LST, note the secondary maxima at 2400 to 0100 LST. These times are in close agreement with those noted at Innsbruck in the Austrian Alps and at Ispra in the southern Italian Alps. Wind speeds vary greatly. Winds observed by Bossolasco (1950) in the cases cited ranged from 9 m/s (18 kts) to 23 m/s (44 kts). Higher speeds have occurred during very strong foehns, but data for those occurrences are not available.

In contrast to the almost exclusively "north" foehns of the Po Valley, the Lombardy-Piedmont region experiences the "southwest" foehn of the central and northern Apennines. Table 12 gives data representative of such foehns. The statistics are for 1957 to 1966 and were gathered by Murri (1966) from the Macerata Meteorological Observatory (43°17'45" N, 13°27'08" E, elevation 338 m (1,110 ft)).

TABLE 12. Average Monthly and Annual Foehn Days at Macerata, Italy.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Days	1.8	1.5	1.9	1.5	1.6	1.7	1.5	0.8	0.8	1.0	1.6	2.4	1.5
Hours	13	10	13	9	11	13	11	7	6	7	8	14	10

Note: Both frequency of occurrence and average duration are considerably less than that shown by Bossolasco (1950) for the Po Valley-Lombardy-Piedmont region. Relative distributions, however, are similar in both regions.

Wind speeds associated with Apennines foehns average 7 to 15 m/s (14 to 29 kts). During the 10 years of record, peak speeds were 20 m/s (39 kts). Damage to buildings and vegetation indicates that foehn winds in certain west to east valleys reach much higher speeds under extreme conditions (Gazzola 1959).

Both Murri (1966) and Gazzola (1963) found that the same synoptic conditions required for foehn onset are also required to produce leeside standing waves (or "mountain waves"). These conditions are:

- 850mb winds averaging 7 to 17 m/s (14-33 kts) with extreme gustiness at the surface, the peak gusts averaging 28 to 36 m/s (54 to 70 kts).

- A well developed surface low pressure system covering all of northern or northwestern and central Europe, with isobaric configuration over Italy parallel to a southwest through northeast axis. A well developed low at 500mb also lies to the west and/or north of Italy. The 500mb flow is well developed, moving from either the southwest or west.

- Well developed jet streams from the west or southwest over north central Italy and central Europe.

- Frontal systems, often moving from southwest to northeast. Fronts may undergo frontolysis while crossing the Apennines toward the Adriatic coast.

At Innsbruck, Austria, the Inn Valley is open towards Alpenvorland, north of Innsbruck. A north wind can frequently enter the valley without crossing the Kalvendel Gebrige Mountains, but a south wind cannot enter without crossing the Zillertaler Alpen or the Stubaier Alpen. As a result, south wind foehns at Innsbruck are more common than north wind foehns. Anticyclonic foehns are fairly common because of the outflow from the valley entrance.

In the Bohemian region of Czechoslovakia, Lanser (n.d.) studied the foehn winds around Krusne hory (50° 30' N, 13° 15' E), the Rudohori, the Sumva, and the Krkonsoe Mountains. Lanser found that foehn winds can occur in any part of the Bohemian Moravian Highland. In the Moravian region, foehns occur around Hosrnske urchy and the Jesenils Mountains, while in the Slovakia region, foehn winds may be found near Male Karpaty, the Beskydy, the Kremmiche hory and the Tatra Mountains.

6.3.1 Tatra Winds. In and around the Tatra Mountains of Poland and Czechoslovakia, foehn winds occur an average of 80 days a year. Some examples of winds in the Tatras are the "Ryterski," observed near Stary Sacz on an average of 73 days a year, the "Rymanowski," observed near Rymanow 13.5 days a year, and the "Halny," occurring on an average of 81 days a year at Kasprowky Wierch. All these winds occur most frequently in autumn or winter, less frequently in summer. The winds reach 20 m/s (39 kts) and occasionally exceed 30 m/s (58 kts) near Stary Sacz (Lewinska 1958). Wind speeds exceeding 60 m/s (117 kts) in gusts have been recorded at Kasprowky Wierch. Another foehn-type wind that occurs near Kasprowky Wierch is the southwesterly or southeasterly "Orawski." The speed of the Orawski is generally less than the halny, but speeds of 53 m/s (103 kts) have been recorded at Kasprowky Weirch (Ordicz n.d.).

Quantitative data on foehn winds in the Tatra Mountains are scarce because few weather stations in the area have been equipped with recording anenometers. A paper by Orlicz (n.d.) gives the best data available.

Tatra Mountain foehns, although as common as foehns in the Alps, are considered phenomena of the northern and northeastern slopes; Czechoslovakian climatologists consider the downslope winds on the southern and southwestern sides of the Tatras as "bora" winds. Evidence of damaging foehn winds in the form of tree blowdowns and other damage is widespread through valleys on the northern slopes of the Tatras. Valleys known as favored locations for strong foehn winds include Dolina Bialej Wody (White Water Valley) on the north slope of the High Tatras, along with Dolina Bystrej, Dolina Suchej Wody, Koscielisko, and Chocholowsko, all in the Western Tatras.

A representative distribution of Tatra Mountain foehns for an exposed station (Kasprowy Wierch) and for a protected valley station (Zakopane) is given in Table 13.

TABLE 13. Mean Number of Days with Foehn at Kasprowy Wierch and Zakopane, Poland.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Zakopane	3	3	2	2	1	1	1	1	1	1	2	3	19
Kasprowy Wierch	10	8	8	5	4	4	3	4	6	9	10	11	82

Totals for Kasprowy Wierch are similar to those for Innsbruck, Austria. The Innsbruck winter maximum is also present at exposed sites. A winter maximum, although considerably less, is also observed even in protected valley locations like Zakopane. Mean foehn durations are the same as at Innsbruck--2 days. However, foehn conditions lasting 11 days have been recorded.

Predominant foehn directions over most of the Tatras are from southeast through southwest. Peak speeds as high as 69 m/s (137 kts) have been recorded over and just north of the main Tatra ridge crests; peak speeds as high as 30 m/s (59 kts) have been recorded even in protected valley locations. Directions over the somewhat lower western Tatras are the same as those over the main ranges. But peak speeds at and just north of ridge crests are somewhat lower; the highest recorded was 53 m/s (104 kts).

6.3.2 Koszawa Orkoschava Wind. The Koszawa Orkoschava is a squall-type southeasterly or northeasterly wind that descends from the Carpathian Mountains into the Danube Valley of Romania and Yugoslavia. It flows as far west as Belgrade, as far north as Wegier, and as far south as Nis. In winter, it brings a temperature drop; in summer, great amounts of dust. The winter Koszawa Orkoschava occurs with a low over the Adriatic Sea and a high over the central and southern part of European Russia. According to some authors, the summer version is caused by the tunnel effect from the Zelazna Brama. Others say it is a katabatic wind, varying between a bora and a foehn. The Koszawa has a pronounced daily cycle, with its maximum between 0500 to 1000 LST.

In the region northeast of Yugoslavia's Dinaric Alps, foehn winds that may influence most of continental Yugoslavia are found (Martyn 1977, Cadez n.d.). These winds occur with cyclonic southwesterly circulation to the lee of the Julian and Dinaric Alps. Some areas experience the greatest frequency of foehn winds in spring (Wallen 1977), others in the cold half of the year (NIS Yugoslavia 1964). At

Zagreb, there are 70 days a year with foehn winds, while Sarajevo (43°52' N, 18° 25' E) sees them about 100 days a year. The strongest influence is felt in the Bosna Valley. Winter temperatures are about 6° C higher during foehns. Summer temperatures increase by about 2° C and the relative humidity in valleys and basins decreases by about 10 percent (Wallen 1977). The speed of the descending air is quite strong, making the area especially dangerous to low-flying aircraft. A good example is a recorded speed of 35 m/s.

6.3.3 Sukhovei Wind. Northerly foehn winds affect Hungary in all seasons (NIS Hungary 1964). They also affect parts of Bulgaria and Romania. In Romania these winds are called the "Sukhovei" and, if persistent, bring prolonged periods of drought and crop damage. A Sukhovei wind occurs when speeds are 5 m/s (10 kts) or more with temperatures equal to or greater than 25° C (77° F), and relative humidity 30 percent or less. The Sukhovei occurs most frequently from April though July. There are two regions of maximum occurrence: The Oltenia Plain in southwestern Romania (4 to 5 days a year) and the Baragan region in eastern Romania (4 to 6 days a year). The maximum in the Baragan region is directly associated with the Russian Sukhovei. The winds, are primarily easterly, while the winds in the western maximum region may be westerly. These westerly winds are supplemented by foehn winds from the surrounding mountains and the region is less exposed to the easterly flow from Russia. Foehns may also occur in the Baragan region when the general flow is from the north or northwest. There is a high foehn frequency just southeast of the bend in the Carpathians on the Romanian Plain. Pronounced northerly foehn winds occur frequently on the lower parts of steep slopes, such as those in the Apuseni, Mehedinti, and Vulcan Mountains of Romania. For south or southwesterly winds, the same phenomenon occurs in the Olt region and the Sibiu Depression (Radiatia 1960).

Foehn winds occur frequently to the north of the Vitosh, Rhodope, and Balkan mountains of Bulgaria. Their life spans vary from several hours to several days. The foehn is also observed at locations south of the Balkans, such as at Sofia, where damaging winds have been observed (Khristov, n.d.). A study by Chapanov and Dragiyeva (1968) for the Sofia airport region yields some data on the downward vertical speeds associated with well developed "high" foehns. Atmospheric soundings have shown that downward vertical speeds in the core of foehn winds coming down the mountains toward the Sofia airport have approached 12 m/s (40 ft/sec). It is obvious that the speeds reached by these descending air currents offer extreme flight hazards to airport traffic.

Foehn winds are most prevalent during winter in the eastern portion of the Black Sea coastal region. In descending from the mountains to the Black Sea, there is a rapid rise in air temperature, sometimes as much as 17 to 29° C (30 to 40° F), and a corresponding decrease in relative humidity. These winds are so dry at times that vegetation withers and any snow on the ground rapidly disappears. Foehn winds are responsible for the barren conditions in many of the foothills in this region. Although foehn winds do occur over most of the rest of the area in winter, they do not appear to be as significant near the Black Sea and are probably beneficial in tempering the rigors of winter. During the rest of the year, foehn winds primarily affect those parts of Turkey to the south of the mountain ranges.

Foehns are prevalent and effective on the northern slopes and adjacent lowlands in the western portion of the Caucasus Mountain region. At Tbilisi, USSR, they occur on an average of 45 days a year (Lewinska 1958). From 1932 through 1947, foehns occurred on an average of 19 days a year at Ordzhonikidze and Maykop, for an average of 3 days a month from December through March. An extreme example is the foehn that lasted 12 days at Ordzhonikidze in April 1943. Another lasted for 10 days at Maykop in April 1939.

Foehns along the northern slopes of the Bol'shoy Kavkaz always develop against a background of southerly winds. These foehns can be divided into two types according to their origin: cyclonic or anticyclonic.

Cyclonic. Most foehns are caused by the passage of a cyclone to the north of the mountains. After the passage of the cyclone and the accompanying cold front, the winds shift to the west and northwest, providing upslope flow that causes the foehn to diminish. Foehns initially affect the valleys of the western Bol'shoy Kavkaz. As the cyclonic system moves to the east or northeast, it also affects the valleys of the eastern mountains.

Anticyclonic. Anticyclonic foehns develop with the passage of a high pressure system from the west or northwest that drifts toward the southeast when it reaches the longitude of eastern Ciscaucasia in southern Russia. The resulting southeasterly and southerly flow is necessary for foehns to develop. Highs of this type activate the Black Sea depression, causing intensification of the southerly flow. Under these conditions, the foehn effect in the western half of Ciscaucasia is even more pronounced because the air descends after crossing the Stravropol "skaya Vozvyshennost." The foehn effect on the plateau is greater during the winter half of the year (NIS USSR, Caucasus 1961).

In the eastern Georgian USSR, just south of the Caucasus Mountains along the Rioni River Valley, foehn wind frequency is shown by 30-year data from three representative sites. Records show that Tsipa experiences 4 weak foehns a year, none strong; at Kutaisi, 21 weak, 0.6 strong; and at Poti, 8 weak, 0.1 strong. The foehn winds in this region normally have an easterly wind component (Vorontsov n.d.).

6.4 **Bora Winds.** The bora is a dry, cold and gusty, "fall" or "downslope" wind that occurs primarily during the winter half of the year (October to April) (Putnick 1943). Four types of bora affect Europe: Two are cyclonic, two anticyclonic. When the pressure gradient over an area is due mainly to a high pressure system, the bora is said to be "anticyclonic." Boras are said to be "cyclonic" when the pressure gradient is due mainly to a low pressure system over the Adriatic or Mediterranean seas. But each of the four bora types is distinguished by the location of the HIGH pressure area associated with it, even though two of them are caused by a LOW pressure system. (Tamiya 1972,1975). Figures 6 through 9 (after Yoshino 1971) show typical surface pressure patterns for each of the four principal bora types.

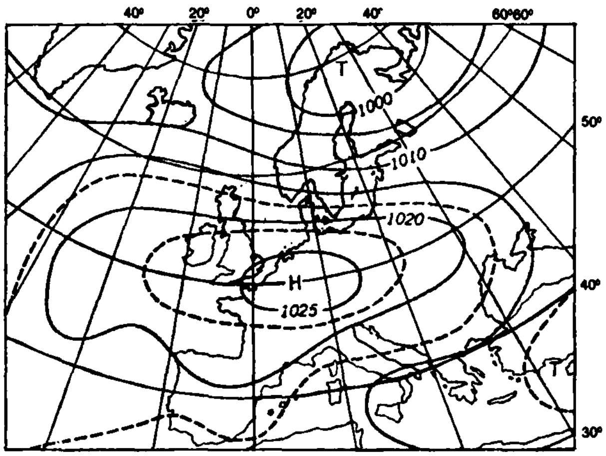


Figure 6. Typical Surface Pressure Pattern, Bora Type ANTICYCLONIC "A." The center of high pressure is quasi-stationary over Central Europe.

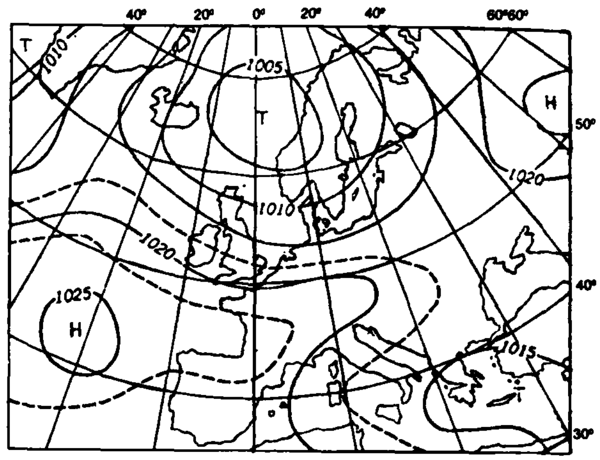


Figure 7. Typical Surface Pressure Pattern, Bora Type ANTICYCLONIC "B." The center of high pressure is quasi-stationary over the Atlantic Ocean, with ridging eastward over Central Europe.

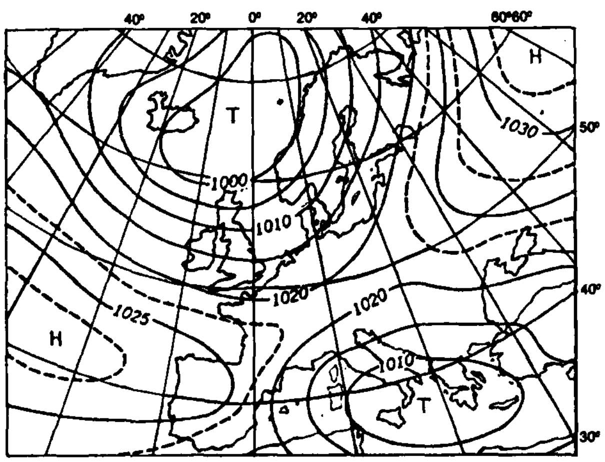


Figure 8. Typical Surface Pressure Pattern, Bora Type CYCLONIC "A." The center of high pressure crosses Central Europe, with a deep depression over the Central Mediterranean.

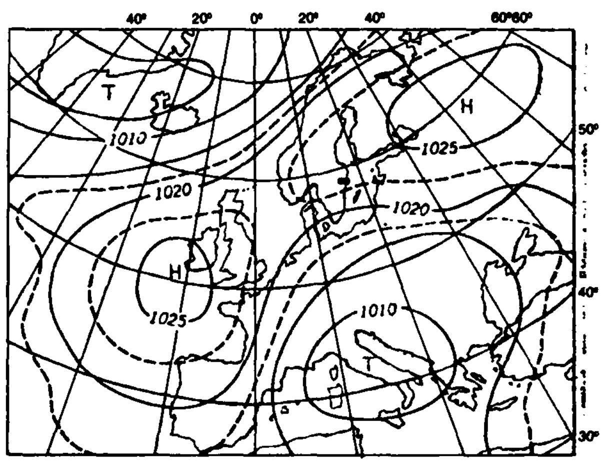


Figure 9. Typical Surface Pressure Pattern, Bora Type CYCLONIC "B." The center of high pressure crosses the Scandinavian Peninsula, with a strong depression over Italy.

According to Yoshino (1976), the general characteristics of a bora include:

- Frequent winter occurrence of wind speeds over 15 m/s (30 kts)
- January and February air temperatures below 0° C (32° F).
- Relative humidity less than 40 percent (anticyclonic bora).
- Stronger boras blow at night, normally reaching maximum strength in early morning (0500 to 0800 LST).
- Duration of 12 to 20 hours in most cases.
- Persistence of more than 10 days in exceptional cases.

A cold polar outbreak in Eastern Europe (cyclonic type A, Figure 8) plays a large part in Yugoslavian boras (Tamiya 1972). Cold air from Eastern Europe is forced to collect and deepen on the eastern side of the Carpathian Mountains. When that air mass is so cold that even a descent to higher pressure levels cannot warm it to equal the temperature of the surrounding air, the phenomenon is known as a "bora wind."

Bora winds are violent for two reasons: the gravity effect, and the jet, or venturi, effect. The gravity effect is from the conversion of potential to kinetic energy as cold air rushes down the lee side of a mountain. The "jet effect" describes the flow of air currents around mountains and through narrow mountain passes and gaps (Arakawa 1973). Boras are especially severe where mountains ridges are higher than 800 m (2,624 ft) and within 2 km (1.2 mi) of the coast (Yoshina 1976).

About two-thirds of the boras affecting Yugoslavia are anticyclonic (Polli 1956). When they occur, a "kapa" cloud (or foehn wall cloud) covers the Dinaric alps while clear skies prevail throughout the rest of the region. The wall cloud is a consistent feature of the anticyclonic bora. However, the existence of a wall cloud does not guarantee the presence of the bora, since a northerly or easterly non-bora wind will often produce the same effect (Meneely 1973).

Winds in southwestern Croatia are reinforced by the topography of the Dinaric Alps, as illustrated in a 1978 study by Loncar. A marked channeling effect for winds above 14 m/s (25 kts) was shown by using data from Gospic [44°33' N, 15°22' E, elevation 546 m (1,850 ft) MSL] for 1966 through 1975. Such effects were observed only in November, December, and February, and occurred only 0.9 percent of the time during the period studied. Observed wind directions showed the following frequencies (percent of the time): NNE 0.1, NE 0.2, ESE 0.1, SE 0.1, and S 0.4. Stations in open terrain do not show the marked channeling effect or increased wind speeds. Gospic lies in a river valley on the immediate eastern side of the Dinaric Alpine ranges. The most favored synoptic situation for these winds is when southwest Croatia is in the air ahead of a frontal system advancing eastward across Italy.

The bora is best known for its effects on the coastal Adriatic Sea areas. It affects the entire Yugoslavia coast, almost all of Albania, and eastern (especially northeastern) Italy, but is especially prevalent on the eastern Adriatic Sea from Trieste, Italy, to Albania (USWB 1944). Wind speed varies with terrain, blowing more violently through mountain gaps and narrow valleys. The wind begins suddenly, accelerating as cold air spills over the Dinaric Alps of Yugoslavia toward the Adriatic Sea. There is usually a sudden temperature rise at the beginning of a bora, followed by a temperature drop (Yoshino 1976). The town of Hvar, Yugoslavia, has seen temperatures fall from 18° C (64° F) to -4° C (24° F) shortly after the onset of bora winds. The average speed of a well-developed bora is about 36 m/s (70kts) (2 WW 1970, 1977). Examples of maximum recorded gusts are given in Table 14 (NIS Yugoslavia 1964).

TABLE 14. Maximum Bora Wind Gusts, Selected Cities.

City	Maximum Speed (m/s)	(kts)
Split, Yugoslavia	30	58
Pula, Yugoslavia	25	48
Zadar, Yugoslavia	20	38
Ulcinj, Yugoslavia	17	33
Titograd, Yugoslavia	27	52
Ajdovscina, Yugoslavia	60	117
Trieste, Italy	43	84

The stronger bora winds along the Adriatic coast are found at Senj, Yugoslavia. They weaken with distance from the coast except in mountain passes or gaps. The strongest bora is observed up to 800 m (2,600 ft) on the lee side due to the damming of the cold air. The height of a bora wind's influence on

the Adriatic coast is usually below 2,500 m (8,200 ft) with an average vertical speed of 5.3 m/s (10 kts) (Yoshimura n.d.).

Stations along the Adriatic Coast of Yugoslavia show another complicating factor. With moderate bora conditions (5 to 10 m/s (10 to 19 kts)), low level winds under 1,600 m (5,246 ft) can retain their land or sea breeze circulation. A study by Makjanic (1959), using data from 1956 only, seems to indicate this possibility. In 22 of the cases with moderate boras (as defined above), he found continued normal sea breeze circulation.

An Adriatic Coast bora day is defined as a day with winds from north to east and peak gusts exceeding 10 m/s (19 kts). Records for 1956 to 1965 show that during any given year, Ajdovscina experienced from 1 to 22 bora-days, Trieste from 2 to 23. The longest period of consecutive bora days was 20 at Ajdovscina and 18 at Trieste (Yoshimura n.d.). The average duration for a winter bora is 3 days, but the examples given for Ajdovscina and Trieste show that much longer periods are possible (USWB 1944).

Boras often last for 5 or 6 days. The sequence begins with the cyclonic bora bringing clouds and rain (NIS Yugoslavia 1964), and ends with the fair skies of the anticyclonic bora (Tamiya 1972). Although all four bora types occur with the same frequency in winter, anticyclonic boras (with high pressure centers over the Atlantic Ocean) are most frequent in summer, with mean maximum winds of 16 m/s (30 kts).

TABLE 15. Average Monthly Frequency (days) of Bora Winds at Trieste, Italy.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
8	8	4	2	1	0.4	0.8	1	2	3	5	6	39

TABLE 16. Total Number of Bora-days on the Adriatic coast, 1959-1965.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
110	95	96	77	73	68	60	70	63	105	95	106	1018

The north to east bora flow from the coastal regions of northern Italy and Yugoslavia continues across the Adriatic Sea to visit other parts of Italy. In particular, the east-northeasterly flow from Trieste sweeps across the Adriatic Sea to the Tre-Venezie Plain (Camuffo 1979). According to S. Polli (1956), this current moves west-southwestward along a 25 km (16 mi) front with only a small erosion of wind speed at Trieste, then continues across the Adriatic Sea. Bora speeds at Chioggia, on the Italian coast some 130 km (81 mi) away across the head of the Adriatic, average 70 percent of speeds at Trieste. Once this current moves inland, however, speeds diminish rapidly. Wind speeds at Rovigo, about 40 km (25 mi) inland from Chioggia, have decreased up to 27 percent of those at Trieste. On either side of the 25 km (16 mi) wide bora "front", wind speed decreases rapidly; noticeable bora winds are absent beyond 10 km (6 mi) of the edges of the bora current. At Vieste, Italy, boras are frequent, but less violent, than those at Trieste. Boras are infrequent south of Vieste (Wallen 1977). The median speed of bora winds in Italy varies, as shown in Table 17 (Polli 1956).

TABLE 17. Median Bora Wind Speed, m/s and kts, for Selected Italian Cities.

Season	Trieste	Lido	Chioggia	Rovigo	Treviso	Padova
Summer	14.5/28.2	8.3/16.1	9.1/17.7	3.6/7.0	3.3/6.4	2.5/4.9
Spring	12.8/24.9	8.6/16.7	9.2/17.9	3.3/6.4	3.3/6.4	2.7/5.2
Winter.	10.6/20.6	7.5/14.6	9.7/18.8	3.0/5.8	3.1/6.0	2.9/5.6
Autumn	14.2/27.6	8.6/16.7	9.1/17.7	4.1/8.0	3.1/6.0	2.5/4.9
Annual	13.1/25.4	8.3/16.1	9.2/17.9	3.5/6.8	3.2/6.2	2.6/5.1

6.4.1 Tramontana Wind. The Tramontana winds resemble the bora, and are often referred to as a type of bora. They occur in northern Italy when cold air crosses the Alps and descends into the Po Valley, and are most common during winter and spring. The Tramontana is caused by high pressure over Central Europe and low pressure over Italy, a combination that brings dry northerly or northeasterly winds into the region (2WW 1977). The appearance of the Tramontana wind is characterized by a reduction in cloudiness and precipitation, followed by clear skies and rapidly falling temperatures (Charli, 1930). "Tramontana" is also a general name for the cool, dry, northerly winds on the backside of east-bound disturbances that affect the entire Mediterranean region (Elliot 1953).

Tramontana winds are especially frequent from October through February, with a maximum in January. A study of Tramontana winds at Vigne de Valle from 1912 to 1928 (Charli, 1929, 1930) provided the data for Tables 18 through 21.

TABLE 18. Total Days with Tramontana Winds at Vigne de Valle, Italy, 1912-1928.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
35	24	14	7	8	9	15	11	9	23	30	39

Charli also found that Tramontana wind speeds vary with altitude, increasing in speed up to about 1,200 or 1,400 m (3,936 to 4,592 ft), and decreasing thereafter as shown in Tables 19, 20, and 21.

TABLE 19. Wind Speed (m/s) with Altitude for Weak Tramontana Winds Starting at the Surface: Vigne de Valle, Italy.

	Altitude (Meters)											
	Sfc	400	600	800	1000	1200	1400	1600	1800	2000	2500	3000
Jan	2.7	3.4	4.0	5.7	6.0	4.9	4.8	4.8	4.9	6.3	6.7	7.6
Feb	4.2	5.8	7.2	8.5	7.5	7.9	9.0	8.2	8.8	.	.	.
Mar	1.7	4.5	5.5	6.2	5.8	6.4	6.9	7.1	.	7.4	8.5	.
Sep	3.4	4.9	6.4	8.5	9.0	6.4	5.1	5.0	4.9	4.6	.	.
Oct	3.5	5.1	5.4	5.6	5.2	5.6	4.7	4.6	5.6	5.9	5.9	6.0
Nov	3.1	4.5	6.5	6.3	6.5	4.7	5.2	5.8	7.3	7.7	7.5	6.8
Dec	3.3	4.1	3.7	3.8	4.7	3.5	3.1	3.6	3.9	4.3	.	.

TABLE 20. Wind Speed (m/s) with Altitude for Strong Tramontana Winds Starting at the Surface: Vigne de Valle, Italy.

	Altitude (Meters)											
	Sfc	400	600	800	1000	1200	1400	1600	1800	2000	2500	3000
Jan	11.2	9.5	12.4	13.7	13.1	13.7	9.9	9.9	8.8	7.9	.	.
Feb	11.3	8.2	12.2	12.8	11.3	11.3	9.5	8.7	8.7	.	.	.
Mar	11.9	11.1	16.1	15.1	11.2	11.0	11.1	8.3	9.9	9.1	.	.
Sep	8.8	8.8	12.4	10.7	9.2	8.0	6.8	5.8	4.6	5.5	8.8	.
Oct	9.1	7.9	11.2	11.5	12.1	5.7	5.4	5.7	6.2	6.4	7.2	.
Nov	11.8	10.3	13.6	14.4	12.2	7.3	7 3	8.3	10.1	.	.	.
Dec	12.2	9.2	12.6	11.9	11.7	12.2	8.9	8.6	7.8	7.5	. .	.

TABLE 21. Average Wind Speed (m/s) with Altitude for Tramontana Winds Starting at the Surface: Vigne de Valle, Italy.

	Altitude (Meters)										
	Sfc	400	600	800	1000	1200	1400	1600	1800	2000	2500
Apr	9.5	9.1	10.6	12.3	13.5	14.1	8.9	9.1	5.7	5.8	6.2
May	5.7	5.5	7.8	8.4	7.0	6.2	6.8	6.9	5.8	5.9	8.2
Jun	4.2	5.2	6.0	5.4	5.3	5.6	5.6	5.5	5.5	6.2	6.9
Jul	6.2	7.1	9.2	8.0	7.5	7.1	7.3	5.8	5.8	7.1	8.2
Aug	7.1	6.4	9.0	9.5	8.4	8.7	8.9	8.4	8.2	7.4	8.6

On Tramontana days from September to March, the turning of the winds with height depends on the strength of the Tramontana wind. If the Tramontana is weak in the boundary layer, the wind near the surface is from north to northeast. At about 1,000 m, however, it turns progressively to the NNW and occasionally to the west. If the Tramontana is strong, winds near the surface are from the NNE or northeast up to about 1,000 meters. At the 1,000 m point, winds turn toward the ENE and sometimes, but rarely, east. From April to October the Tramontana frequently rotates towards the ENE with higher altitude, showing the same variations as with strong Tramontana winds (Charli 1929, 1930).

6.4.2 Bise Wind. Bise winds are similar to the Tramontana, and are associated with the advection of cold continental air in Switzerland. Bise winds are generally cold, dry, and moderately strong, with bora characteristics. They can become very strong in mountainous regions where there is a jet effect. In Lausanne, above Lake Geneva, they are north or northeasterly with speeds that may reach 25 m/s (48 kts). They are observed from 157 to 176 days a year, but occur most often in April and May.

6.4.3 Polak Wind. In northeastern Czechoslovakia, near the Polish border, there is a cold autumn northeasterly that takes on the characteristics of a bora. The local name for it is "Polak". It is preceded by a single strong gust followed by a steady wind of great speed, with exceptionally strong gusts. A 4 March 1925 Polak wind in the Moravia Gate registered intensities up to 21 to 24 m/s (41 to 47 kts). The bora wind of the Bohemian Suduatian is also called the Polak. Atmospheric pressures during Polak situations are higher to the northeast of mountain barriers.

6.4.4 Boehmischer Wind. The Boehmischer wind (German for "Bohemian or Czech wind") is a cold and gusty easterly, similar to a bora, that descends into Bavaria and the Bohemian Forest from the Bohemian basin of Czechoslovakia. It occurs with a high pressure system over the eastern portion of central Europe. It appears in all seasons, but most frequently in winter (Schramm n.d.). Due to large pressure differences between different regions of the Carpathians during the winter, high-speed bora-type winds develop along the slopes of the Bistrita, Gurghia, Harghita, and Bucegi Mountains of Romania (Radiatia, 1960).

6.4.5 Kossava Wind. The Kossava is a cold east or southeast wind affecting northeastern Yugoslavia, Hungary, and the southern part of the Romanian plains. It usually occurs between October and March, lasting anywhere from 2 days to 2 weeks. Cold air from an extensive high pressure system over central Europe and Ukranian Russia, along with a low pressure system in the Tyrrhenian or Adriatic Seas south to southwest of Yugoslavia, trigger the onset of the Kossava (NIS Yugoslavia 1964). Cold air gathering in the Ukrainian basin eventually blows through the "Iron Gate" where the Danube River flows through the Transylvanian Alps, then northward into southern Hungary. The Kossava acts as another bora-type wind in Hungary, dropping surface temperatures to well below -18° C (0° F) (NIS Hungary 1964). The air then travels into Yugoslavia where it affects areas north and northeast of the line Nis-Kraljevo-Cacak-Valjevo-Bjelina-St. Mitrovica-Vukovar-Sombor-Subotica (Putnick, 1943). Kossava speeds average about 13 m/s (26 kts) (NIS Yugoslavia 1964), but gusts to 33 or 40 m/s (64 to 78 kts) are possible (Putnick 1943). Speeds vary diurnally, with maxima between 0500 and 1000 hrs LST. (NIS Yugoslavia 1964). Even though Yugoslavian Kossavas result in increased, not decreased, temperatures, their low relative humidities and high wind speeds cause them to be regarded as cold winds (Wallen 1977). The Kossavas' low temperatures, strong winds, and poor visibilities make outdoor activities extremely hazardous. Kossavas may also occur in summer months, but only rarely. When summer Kossavas do occur, they can trigger widespread duststorms (NIS Yugoslavia 1964). Hungary may experience Kossavas at any time of year because of a high pressure system in western Europe. If the air moving south is partially blocked by the Alps and the Carpathian Mountains, winds blow through a gap near Vienna and spread out over western Hungary (NIS Hungary 1964).

6.4.6 Crivetz Wind. The Crivetz wind of southern Romania is a strong and gusty, severely cold wind from the Ukraine. It occurs frequently in spring and autumn, and regularly during winter (2WW 1970). Twenty percent of all winds in the Bucharest area are of this type. The Crivetz is northerly through easterly, with the character of a bora in Romania and the southern part of European Russia. It is dry and cold in winter, hot in summer. It develops with a high pressure system over the northeastern part of Europe and a developing low pressure system over the Mediterranean Sea (Martyn 1977).

6.4.7 Nemere Wind. The Nemere wind is a cold and strong westerly or southwesterly that blows down the Danube Valley, particularly in Transylvania, and on the Romanian Black Sea coast. It develops on the trailing edge of a low over the Black Sea, causing blizzard conditions and significant temperature drops (Martyn 1977).

6.4.8 Liva Wind. The Greek gravity wind called the "Liva" (NIS Greece 1961) is most common in the western mountains of northern Greece, and is the result of cold air drainage down mountainsides. Channeling effects often increase the wind speed, while wind direction is dependent on the terrain.

6.4.9 Vardarac Wind. The "Vardarac" wind is a cold dry northerly that blows along the Vardar River Valley into the Gulf of Salonika. Although it may occur during any season, it develops most frequently during winter when high pressure dominates the Balkans and pressure over the Aegean Sea is significantly lower. The Vardarac is triggered when a cold air sink develops in the Skopje Basin of southern Yugoslavia and moves into the Vardar River Valley. While its north-northwesterly direction imitates the bora, the Vardarac is less gusty. Average wind speed is about 5 m/s (10 kts), but gusts can be as high as 20 m/s (39 kts). The Vardarac can be felt to altitudes of 1,500 m (4,920 ft) (Wallen 1977, Putnick 1943, Martyn 1977).

6.4.10 Struma Wind. Under conditions similar to those for the Vardarac, the Struma wind flows through the Struma Valley of northern Greece into the Orfanichy Gulf. The Struma is also similar to the bora. Strumas last 2 to 3 days, with speeds of 5 to 7 m/s (10-14 kts) and gusts to 15 m/s (29 kts) (Martyn 1977).

6.4.11 Raghieh Wind. One of the most prevalent local winds over Turkey is the Raghieh, a cold fall wind that occurs primarily in winter. Raghiehs are most pronounced along the Aegean Sea coastal region. Although cold air from the north spills into the Aegean Sea in autumn through spring, the

Raghieh's frequency and violence are greater in winter. If there is a low in the Mediterranean, clouds, thunderstorms, and rain or snow squalls are associated with the Raghieh. Otherwise, skies are usually clear. Raghiehs bring fairly low temperatures to the west coast of Turkey. They may continue for as long as 7 or 8 days, with speeds sometimes exceeding 26 m/s (50 kts) in squalls.

6.4.12 The Novorossiysk Bora. The name is given to a cold, strong northeast wind descending from the mountains near the Black Sea coast between Novorossiysk and Tuapse. This local bora develops when the pressure gradient in the northeastern part of the Black Sea basin decreases from north to south or northwest to southeast. It is only when the pressure gradient assumes this direction that the flow can be directed from the mountain slopes along this section of the Black Sea coast. Although the pressure gradient can be slight, its configuration combined with the height of the range (490 to 610 m--1,600 to 2,000 ft) is necessary (and sufficient) for bora development immediately after passage of an east-west cold front. The Novorossiysk Bora intensifies sharply when a low appears over the Black Sea. Under these conditions, wind speeds often reach gale force, sometimes hurricane strength. When the front associated with the Black Sea cyclone is strongly occluded, the bora occurs with little cloudiness. When the cyclone still has a warm sector, or contains large amounts of warm, moist air (even if aloft), the bora is accompanied by overcast clouds and precipitation. In winter, freezing precipitation is common. Winds are very gusty. The strength and frequency of the Novorossiysk Bora are due to the adjacent Pereval Markotkh mountain pass (44° 45' N, 37°49' E), which acts as a venturi to compress the Northeasterly flow. Another factor is the low profile of the mountain range's southwestern slope. Farther to the south, where the height of the range increases, the bora development tendency weakens. South of Tuapse, the winds become more foehn-like. The highest wind speed ever recorded at standard observation times during a Novorossiysk Bora was 36 m/s (70 kts). Wind speeds in the Pereval Markotkh are two to three times greater than at Novorossiysk, and the temperature is considerably lower. The bora occurs most frequently from November through March, averaging 5 days a month at Novorossiysk. The average duration is 3 days, but a maximum duration of 17 days was recorded in November, 1935. While warm season boras occur less often, they can be just as violent. For example, bora gusts from 15 to 17 May 1966 reached 35 to 40 m/s (68 to 78 kts) at Anapa, Novorossiysk, Gelendzhik, and Tuapse along the Black Sea coast (Masterskikh 1972). The winter bora can be extemely destructive. Sharp temperature falls have been known to freeze over the normally ice-free harbor at Novorossiysk. Railroad cars have been blown off their tracks. Ships in the harbor been sunk as a result of rough seas and accumulated frozen spray on superstructures (Masterskikh 1976). If the wind speed along the immediate coast is 30 m/s (58 kts), winds of 8 to 10 m/s (16 to 19 kts) can extend 300 km (186 mi) out to sea. As a result, wind damage to shipping is possible a considerable distance from the coast line (Masterskikh, 1976).

6.5 Jet Effect Winds. Jet (or venturi) effect winds occur in Area II throughout the year. In most cases, they appear as components of other wind types, especially of the foehn or bora, both of which can be significantly intensified by the jet effect. Along the Aegean Coast, winds are often channeled between islands or between an island and the Turkish coast to increase their speeds. The Dusenwind that blows through the Dardanelles mountain gap is one of the best examples. This strong east-northeast wind blows out of the Dardanelles into the Aegean Sea as far as the island of Lemnos. It is caused by a high pressure ridge over the Black Sea (Huschke 1959).

6.5.1 Modified Maloja Wind. The jet effect also intensifies mountain winds as they pass from one valley to another. The Maloja wind is a classic example (See paragraph 6.2.1).

6.5.2 Modified Polak Wind. The Sudetan-Carpathian mountain arc restricts the flow of cold air into Czechoslovakia except where it penetrates into Moravia through the "Moravian Gate". Polar and arctic air masses run through this "gate" at speeds as high as 28 m/s (54 kts). This venturi effect is also seen in the Silesian Sectors of both Germanies. There is some indication that low-level inversions tend to limit the exchange of air between the Moravian side of the Sudetans and their north side. These inversions may also limit the exchange between the Silesian and the north side of the Carpathians (See paragraph 6.4.3).

6.5.3 Modified Kossava Wind. Although the Kossava is generally classified as a "bora" wind, the jet effect causes significant local intensification. According to Milosavljevic (Todorovic, 1978), the strongest Kossava winds occur in the eastern part of the Pannonian Plain. These winds result from a southerly to southeasterly wind blowing through the "Iron Gate," a gorge on the Danube. The gorge acts as a funnel through which cold Siberian air penetrates westward into Yugoslavia whenever deep low pressure centers move eastward over the eastern Mediterranean and into the Black Sea during winter and early spring. A speed of 37 m/s (72 kts) was observed at Vrsac [45°09' N, 21°19' E, elevation 84 m (276 ft) MSL] in March. Speeds drop off markedly as one moves west-northwest towards Belgrade. A study by Milosavljevic (n.d.) shows that gusts above 17 m/s (33 kts) accounted for 70 percent of all winds from 1960 to 1965 (See paragraph 6.4.5).

6.6 Synoptic-Scale Pressure Gradient Winds.

6.6.1 Scirocco Wind. The Scirocco is a hot and dusty southerly wind as it originates over the Sahara Desert. It picks up a great deal of moisture as it crosses the Mediterranean Sea. It affects coastal areas around the Adriatic, Aegean, Ionian, and Mediterranean seas by bringing low clouds and

continuous heavy rain (NIS Yugoslavia 1964). Although very strong along the Adriatic Sea coast, the Scirocco loses momentum quickly after penetrating inland about 30 km (19 mi). Unlike the Bora, the Scirocco begins gently and attains full strength gradually. It reaches gale force (14 m/s, 27 kts) only occasionally. Extensive fog is common in the northern Adriatic Sea. Temperatures rise throughout Scirocco-affected areas (NIS Yugoslavia 1964).

Sciroccos occur in advance of low pressure systems moving south in the Adriatic Sea, or east in the Mediterranean Sea. The most intense Sciroccos occur when there is a well-developed low pressure system in the western Mediterranean Sea at the same time as a secondary low south of Sicily. These conditions bring southwesterly flow to the Gulf of Venice in northern Italy. Cloudy, rainy, and oppressive weather then extends along the entire Yugoslavian and Albanian coasts (NIS Yugoslavia 1964).

Sciroccos typically blow in the colder half of the year, but summer Sciroccos are not unheard of. They bring hot, dry air, relatively unmodified by the Mediterranean Sea, to the southern coasts of Yugoslavia and Albania (NIS Albania 1963), the northern coast of Sicily, and occasionally, southern Italy. The flow around high pressure cells in the Tyrrhenian Sea has pushed the summer Scirocco as far north as Rome. (NIS Italy 1953).

Sciroccos occur in Greece during all seasons. Hot and dry in summer, they bring dust laden air to the southern and central regions. Visibility-restricting dust has been observed by aircraft up to 460 m (1,509 ft). Moist winter Sciroccos bring strong winds and heavy rains to the northern regions of Greece, occasionally causing extensive flooding.

6.6.2 Sirocco Wind. The Sirocco is a dry and dusty desert wind that blows from the south or southeast across Turkey. It occurs primarily in spring, occasionally in autumn. Occurrence of a sirocco may herald the highest temperatures of the year. The sirocco develops as a low pressure center that moves over or near North Africa and draws in extremely hot and dry air from the deserts. As the low center progresses eastward, the dust-laden air is carried northward. Although some modification occurs over the Mediterranean, temperatures on arrival over Turkey are usually greater than 38° C (100° F) and relative humidities well below 30 percent. The Sirocco is most pronouced during the day, with wind speeds reaching their maximum in early afternoon. As the low moves to the east, northwesterly winds bring cool moist air to the southern coast of Turkey and to Cyprus. Temperatures drop as much as 17° C (30° F) in 2 to 3 hours, and relative humidity increases by as much as 50 percent. Ordinarily, Siroccos do not affect the interior highlands or the Black Sea coast, but on rare occasions a strong Sirocco can dominate the whole area. Although not a true Sirocco, there is a cold easterly winter wind that has acquired the name of "Cold Sirocco." It affects the eastern part of Turkey and brings in dry, dusty air that is bitterly cold.

6.6.3 Etesian Wind. The Etesian ("Meltem" in Greece or Turkey, "Maestro" on the Adriatic coast) is a northerly wind that affects the eastern Mediterranean region from May through October or November. Etesians appear regularly each year, with maximum strength and frequency in July and August. Etesians are characterized by their high speeds and directional consistency (Reiter 1971). The already strong Etesian winds (occasionally reaching 14 m/s (28 kts)) may be made still stronger by the channeling effects between the islands of southern Greece. This intensification can cause the winds to be felt as far south as Cyprus. The northerly Etesians extend up to 2,000 m (6,562 ft) with maximum speeds found near 1,000 m (3,281 ft). The transition is larger where the wind shifts from north to west between 2,000 and 3,000 m (6,562 and 9,943 ft) (Gyorgy 1962).

Etesians are caused partly by a monsoon-like flow between the warm landmass of Asia Minor and the cool Mediterranean Sea, and partly by synoptic disturbances that lead to anticyclogenesis over the Balkan Mountains. Typically, the combination of low pressure along the southern coast of Turkey and high pressure over the Balkans is required for the development of the Etesian winds (Reiter 1971).

Etesians usually bring good weather to the Mediterranean region, raising temperatures and lowering humidities. Sometimes, however, they bring overcast skies, or worse. In Athens, for example, Etesians have been known to raise suffocating dust clouds (USWB 1944). A cold front may move south or southeast over Greece as an Etesian regime is established (Reiter 1971). Thunderstorms often occur in the Balkans and in Greece on the day before onset of the Etesian. In Greece, thunderstorms may persist throughout the first day of the Etesian. Thunderstorm maxima occur from May to June and from October to November.

The onset of a July or August Etesian may be predicted the day before by the presence of scattered (mostly altocumulus) clouds in the Aegean Sea area. Orographic clouds may form on some of the islands during the Etesian, particularly if winds are strong. Strong gale force winds occur along the southern coast of Crete during the Etesian season. Gaps between Crete's mountains cause channeling effects and increase local wind speeds. Crete lies outside of the main force of the Etesians (Reiter 1971).

Etesian winds along mainland coasts tend to be more variable than those on the open sea. In Athens, for example, they are always intermittent because of the land and sea breezes (USWB 1944). Sea breezes in Athens oppose the Etesian. One minimum in the northerly Etesian occurs near noon when the opposing sea breeze is stronger. There is a second minimum in early afternoon when the opposite effect of the sea breeze is strongest (Reiter 1971). At Athenai Airport in Athens, strong winds usually do not develop when

surface and 900 m (2,953 ft) wind directions vary by more than 20 degrees (Meyer 1970). In Smyrna, Etesian winds are completely overridden by the land and sea breeze. Studies done at Limnos in the northern Aegean Sea show that the maximum wind occurs before 1400 LST, while at Naxos in the Southern Aegean Sea, maxima occur between 1400 and 1700 LST (Reiter 1971). Typically, the winds start near 1000 LST and end in the evening. The low pressure trough along Turkey's south coast undergoes diurnal intensity pulsations. The resultant winds are reinforced by the sea breeze in the southern Aegean Sea, but along the northern Aegean, Macedonian, and Thracean coasts, sea breeze reinforcement is absent. Instead, the Etesian is opposed by the sea breeze that results from daytime heating of the land and the heating influence on the pressure gradient. Turbulent mixing extending to about 1,000 m (3,281 ft) over land exerts another influence on the Etesian (Reiter 1971).

"Etesian days" in Greece are those in which Athens reports a north wind at noon that counteracts the southerly sea breeze and seems to deny the existence of a considerable pressure gradient (Reiter 1971). The number of "Etesian days" varies annually, and frequency seems to correlate with the 11-year sunspot cycle. A study of "Etesian days" at Hellenikon Airport was used to produce the following table (Reiter 1971).

TABLE 22. Maximum and Minimum Numbers of Etesian Days (Monthly and Yearly), Hellenikon Airport, 1947-1969.

	May	Jun	Jul	Aug	Sep	Oct	Year
Maximum:	13	15	23	23	19	24	60
Year:	1950	1957	1967	1949	1964	1969	1961
Minimum:	0	0	6	2	5	1	27
Year:	1959	1948	1966	1968	1952	1960	1968

Note: The Etesian year is June through September.

The duration of an Etesian period depends on the speed of the system that causes it. For fast-moving systems, Etesian periods are brief, usually 5 days or less. If the trough-ridge pattern is shallow, and westerlies prevail above it, expect another Etesian period follow soon after the first. Slow-moving systems are characterized by deep surface depressions in the region of the Black Sea associated with a 500-mb cut-off low and prevailing northerly winds at upper levels. An extended Etesian period, lasting 5 days or more, begins with strong gusty surface winds. The extended periods usually occur about once a month during July and August. Thunderstorms from these winds often continue for several days in the eastern Balkan Mountains, over northeastern Greece and in northern Turkey (Reiter 1971).

TABLE 23. Monthly Mean Number of Continuous Etesian Days and Number of Cases in which Duration of Etesian was ≥ 5 Days and ≥ 10 Days (60-year period).

	May	Jun	Jul	Aug	Sep	Oct
Mean Number of Continuous Days:	2.2	2.2	3.7	3.6	3.1	2.4
Number of Cases, ≥5 Days:	10.0	18.0	63.0	66.0	64.0	18.0
Number of Cases, ≥ 10 Days:	1.0	2.0	16.0	13.0	10.0	1.0

BIBLIOGRAPHY

This list includes a number of subject-related materials not referred to in the text. They have been included here to provide the reader additional sources of information for detailed study or research.

2d Weather Wing, European Theater Weather Orientation, pp. 4-35, 1970.

2d Weather Wing, European Theater Weather Orientation, pp. 105-112, March 1977.

Alaka, M. A., Aviation Aspect of Mountain Waves, T.P.26, Technical Note No 18., Technical Division of the WMO Secretariat, WMO-No. 68, 1958.

Ambrosetti, Flavio, On the Winds South of the Alps, Observatorio Ticinese Dell'Instituto Svizzero di Meteorologia a Locarno-monti, Nr. 60, pp. 1-25, Sep 1976.

Appolov, B. A., Caspian Sea and its Basin, Academy of Sciences U.S.S.R., Moscow, 1956, translated U.S. Navy Hydrographic Office, 1960.

Arakawa, S., Numerical Experiments of the Local Strong Winds, Bora and Foehn, Climatological Notes, Dept. of Geography, Hosei Univ, Tokyo, pp. 1-3, 1973.

Berenger, M. et N. Gerbier, Les mouvements ondulatoriesa St Auban sur- Durance (Bassess Alpes); premiere campagne d'etudeset de mesures (janvier 1956), Monographic No. 4 de la Meteorologie Nationale, 1958.

Blackadar, A. K., "Boundary Layer Wind Maxima and Their Significance for the Growth of Nocturnal Inversions," Bull Am Met Soc, Vol. 38, No.5, pp. 283-293, May 1967.

Bossolasco, Mario, The Foehn of the Italian Alps, Atti Del Primo Convegno Internazionale di Meteorologia Alpina, Milano, pp. 62-66, 1950.

Cadez, M., On Certain Influences of Orographic Obstructions on the Air Movement, source unknown.

Camuffo, et. al., Local Mesoscale Circulation over Venice as a Result of the Mountain-Sea Interaction, Boundary Layer Meteorology, Vol. 16, pp. 83-92, 1979.

Chapanov, Ts. and A. Dragiyeva, "On Certain Features of the Foehn in the Sofia Region," Khidrologia i Meteorologiya, Vol. 17, Nr. 5, pp. 47-49, 1968.

Charli, M.P., "Les vents de tramontane aux diverses altitudes a la base d'hydravions de Vigne de Valle: Resume de l'etude de Filippo Eredia. (Tramontane winds at various altitudes at the sea plane base of Vorginia de Valle. Summary from the study by Filippo Eredia)," extracted from Rivestia Aeronautica, Vol 5., No. 12, Dec 1929. La Meteorologie, 6(64-66):pp. 386-390, Jul-Sep 1930.

Corby, G.A., The airflow over mountains. Notes for forecasters and pilots, Met Rep No 18, H. M. Stationery Office, p. 53, 1957.

CSMI, Statni meteorologicky ustav: Mesicini prehled meteorologickych pozorovani, Monthly Rev. of Met. Observations, March 1925. Czechoslovakian State Met. Inst., Brezen, 1925.

Defant, Friedrich, Local Winds, Compendium of Meteorology, American Meteorological Society, Boston, MA, pp. 655-672, 1951.

der Lan, H. A., Meteorologische Besonderheiten der Agais.

Ekhart, E., Zur Aerologie des Berg-und Talwindes, Beitr. Phys. frei. Atmos., 18:1-26 (1931).

Elliot, Robert D. and Sidney R. Frank, Operational Weather of the Mediterranean Area, Area I, Report 53-4, Task 9, Final Report No. 1, Contract N1895-86744, Aerophysics Research Foundation, October 1953.

Fetov, F., E.L. Mihai, and St. Cristescu, Climatological Characterization of the Sukhovei Wind in the Romanian Plains, C.S.A. Institutul Meteorologic, Culegere de Lucrari ale Institului Meteorologic, pe anul 1961, Bucuresti, pp. 377-394, 1963

Flohn, Hermann, Frequency, Duration and Nature of the 'Free Foehn' at German Mountain Stations, Beitrage zur Physik der Freien Atmosphere, Nr. 27, pp. 110-124, 1942.

Flohn, Herman, Weather and Climate in Germany (Witterving und Klima in Deutcheland), Technical Report 105-15, Air Weather Service, 1942.

Foerchtgott, Jiri, Flight Meteorology (Letecka Meteorology), Industrial Publishing House.

Forchtgott, J., "Wave Streaming in the lee of mountain ridges," Bull Met Czech, Vol. 3, Prague, p. 49, 1949. (Note: American spelling of author's name is as used in referenced publication).

Frey, Karl, The Development of Southerly and Northerly Foehn, p. 56.

Frey, Karl, Diagnosis of the Foehn, Meteorologische Rundschau, Vol. 10, Nr. 6, pp. 181-185, Nov-Dec 1957.

Gandino, C. and M. De Bortoli, Course of the Speed of the Foehn at Ispra, Observatorio Meteorologico de C. C. R. Euratom, Ispra, Varese, pp. 255-260.

Gandino, Claudio, The Influence of the Alps on the Diurnal Period Winds of the Po Valley, Riveste Italiana di Geofisica, Vol. III, No. 3-4, 6 (English abstract only).

Gazzola, A., Effects of Mountains on Air Currents, Part 1 and 2, Rivista di Meteor. Aeron. 23, 1, 1963; 23, 2, 1963, Rome, 1963.

Gazzola, A., Leeward Undulatory Phenomena of the Northern Apennines with Currents from the Southwest and Considerations of the Structure of the Jetstream, Proceedings of the International Scientific Conference on Jetstreams and Undulatory Currents, Turin, 1959.

Gyorgy, Peczely, Local Wind System of Lake Balaton, Idojaras, Nr. 66, pp. 83-89.

Gyorgy, Peczely, A magyar Alfold es a kornyezo legesereje (Air Exchange between the Hungarian Lowlands and the Surrounding Mountains), Idojaras, Vol. 67, No. 4, p. 233-238, 1963.

Gyorgy, Peczely, A nagyvaros altal keltett helyi szelrendszer Budapesten (Development of city-induced local wind system over Budapest), Idojaras, Vol. 66, No. 6, pp. 354-360, 1962.

Huschke, Ralph E., Glossary of Meteorology, American Meteorological Society, Boston, MA, pp. 182, 1959.

Jeffreys, H., "On the Dynamics of Wind," Quart. J.R. Met. Soc., pp. 29-46, 48:1922.

Kallerman, V., "Recurrence and Direction of the Breeze on the Southern Coast of the Crimea," Meteorologiya i Gidrologiya, Vol. 4, Nr. 9-10, pp. 53-61, Sep-Oct 1938.

Khristov, Penyu Iv., "Gale Winds in Bulgaria," Khidrologiya i Meteorologiya, Nr. 1, pp. 64-76.

Kuttner, J. and C.F. Jenkins, Flight Aspects of the Mountain Wave, Tech Report no. 35, USAF Cambridge Research Laboratory, p. 36, 1953.

KVPRZM, Large-Scale and Regional Climatic Influences in Moravia (Moravo) -Silesia Province, Czechoslovakia, Hrudicka, Bohuslav, Klimaticke vlivy primarni a regionalni v zemi Moravskosleske.

Lanser, Jiri, Foehn Cloud Formations over Czechoslovakia.

Lewinska, Janina, Ryterski and Rymanowski Winds, Przeglad Geofizyczny, Vol.3 (11), Nr. 1, pp. 17-26, 1958.

Loncar, E., Heavy Winds and Weather in the Dinarian Alps, in Proceedings of the 15th International Conference on Alpine Meteorology, pp. 86-88, Sep 1978.

Makjanic, B., The Alternating Effect of Sea Breeze and Foehn, Deutscher Wetterdienst, Berichte, Vol. 8, Nr. 54, pp. 218-220, 1959.

Margules, M., Material zum Stadium der Druckverteilung und des windes in Niederosterreich, Jb. Zent. Anst. Meteor. Wein, 35:D1-16 (1898); 37 (V): 1-15 (1900).

Martyn, Danuta, Local and Regional Winds - their Names and Attributes, Prace: Studia Instytuta Geograficznego Uniwersytetu Warszawskiego, Klimatologia, Vol. 22, Nr. 9, p. 99, 1977.

Masterskikh, M. A., Novorossiysh Bora during the Warm Time of the Year, rudy Gidrometeorologicheskiy Nanchno-Issledovatel' skiy Tsentr USSR, Leningrad, Nr. 109, pp. 34-36, 1972.

Masterskikh, M.A. and G.S. Ioffe, Some Characteristics of the Novorossisk Bora on the Open Sea, Trudy Gidrometeorologicheskogo Nanchno. Issledocatil' skogo Tsentra USSR, Gidrometeorzdat, Nr.179, Leningrad, pp. 31-35, 1976.

Meneely, Jack M., and Earl S. Merritt, Satellite Observations of Anomalous Local Wind Events in the Mediterranean Region, Final Report, EPRF 51-0673-003, U.S. Naval Oceanographic Office, Washington D.C., pp. 45-53, May 1973.

Meyer, Melvin J., An Objective Method of Forecasting Melteme Wind Speeds at Athenai Airport, Greece, Det 4, 21st Weather Squadron, pp. 1-3, 29 Apr 1970.

Michalezewski, Jorzy, Synoptic Conditions of the Occurrence of Sea Breezes on the Polish Coast of the Baltic Sea, Wiadomosci Sluzby Hydrologiezney i Meteorologiczny, Vol. 1(8), Nr. 2(02), pp. 29-40, 1965.

Milosavljevic, M. and K., Contribution to a Knowledge of the Wind Structure in Serbia, p. 14.

Murri, Alfredo, The Katabatic West Winds in the Central Apennines, Rendiconti Dell'Observatorio Meteorologicio di Macerata, Camera di Commercio Industria Artigianato e Argicoltura di Macerata, Series 3, Nr. 2, pp. 3-27, 1966.

NIS, National Intelligence Surveys, Weather and Climate, Section 23, for: Albania (Oct 1963), Hungary (Apr 1964), Italy (Sep 1953), Yugoslavia (Jul 1964), Greece (Jan 1961), Finland (Oct 1965), (Soviet Central Asia (Mar 1960), U.S.S.R., Caucasus (May 1961).

Ordicz, Michael, The Climate of The Tatra Mountains, pp. 76, source unknown.

Ozorai, Zoltan, A zivatarok gyakorisaga Budapest-Ferihegy repulateren (Thunderstorm frequency at Budapest-Ferihegy Airport), Idojaras, Budapest, Vol. 69, No. 6, pp. 375-377, 1965.

Polli, Silvio, "The Bora in the Gulfs of Triest and Venice," Geofisica e Meteorologia, Vol. 4, No. 1-2, pp. 11-12, Jan/Apr 195

Prib, Z.M., Climate Outline of the Kara Sea, Transactions of the Arctic Scientific Research Institute of the Chief Administration of the Northern Sea Route of the U.S.S.R., Vol. 187, Moskva, 1946, Leningrad, translated as Environmental Protection Section Report No. 160, February 1950.

Putnick, D.R., Col., The Main Climatic and Meteorological Characteristics of Yugoslavia, Yogoslav Forces, Aug 1943.

Radiatia, Solara, "Geographic Monography of the People's Republic of Romania," Climate Chapter, Monografia Geografica, pp. 259-359, 1960.

Reinhart, Manfred, Some Flight Observations on the Local Current Conditions during a Southern Foehn in the Area of Innsbruck, source unknown.

Reiter, Dr. Elmar R, Digest of Selected Weather Problems of the Mediterranean, Tech. Paper No. 9-71, NAVWEARSCHFAC, pp. 8-28, 114- 132, (AD 769546). Apr 1971.

Schneider-Curius, Karl, "The Etesians," Meteorologisch Rundschau, Vol.1, Nr. 15/16, pp. 464-470, Sep-Oct 1948.

Schramm, Anton, The Bohemian wind in the area of the Oberphaelz Forest and the Bohemian Forest, source unknown.

Scorer, R. S., "Theory of Waves in the Lee of Mountains," Quart. J. R. Met. Soc., Vol 75, p. 41, 1949.

Scorer, R. S., "Mountain gap winds; a study of surface wind at Gibraltar," Quart. J. R. Met. Soc., Vol 78, pp. 53-61, 1952.

Scorer, R. S., "Theory of Airflow over Mountains: II--The flow over a ridge," Quart. J. R. Met. Soc., Vol 79, p. 70, 1953.

Scorer, R. S., "Theory of Airflow over Mountains: III--Airstream Characteristics," Quart. J. R. Met. Soc., Vol 80, p. 417, 1954.

Scorer, R. S., "Theory of Airflow over Mountains: IV--Separation of flow from the surface," Quart. J. R. Met. Soc., Vol 81, p. 340, 1955.

Scorer, R. S., and N. Wilkenson, "Waves in the lee of an isolated hill," Quart. J. R. Met. Soc., Vol. 82, p. 419, 1956.

Stanchev, K., et al, "Wind Systems in the Free Atmosphere over Bulgaria Described," Khidrologia I Meteorologiya, Vol 4, 1974. In: JPRS63684, Translations on Eastern European-Scientific Affairs, No.445, pp. 19-29, 17 Dec 1974.

Tamiya, Hyoei, Chronology of Pressure Patterns with Bora on the Adriatic Coast, Climatological Notes, Dept. of Geography, Hosei University, Tokyo, pp. 52-63, 1972.

Tamiya, Hyoei, "Bora and Oroshi: Their synoptic climatological situation in the global scale," reprinted from the Abstract of Geographical Review of Japan, Vol. 47, 1974, pp. 264-272 in Japanese Progress in Climatology, pp. 29-34, Nov 1975.

Todorovic, N., and K. Milosavljevic, Influence of the Alps and the Carpathians on the Climate of the Pannonic Plain in Yugoslavia, in proceedings of the 15th International Conference on Alpine Meteorology, pp. 139-142, Sep 1978.

Tokmakov, A.I., Wind Characteristics in the Territory of the Ukrainian Carpathians, source unknown.

United States Weather Bureau, A Brief Summary of Weather Factors as they Affect Military Operations in Turkey, the Middle East, and South- eastern Europe, SR-184, pp. 1-12, 1944.

Vorontsov, P.A., Breezes of Lake Ladoga, Trudy Glavnoy Geofizicheskaia Observatorii, Nr. 73, pp. 87-106, 1958.

Vorontsov, P.A., Local Winds on Lake Sevan, Trudy Glavnoy Geofizicheskoy Observatorii imeni A.I. Volyeyhova, Voprosy Fiziki Atmosfery, Nr. 106, pp. 55-61.

Vorontosov, P.A., The Transformation of Air under the Effect of the Underlying Surface during Sukhoveis and Foehns, source unknown.

Wallen, C.C., Ed., Climates of Central and Southern Europe, World Survey of Climatology, Vol. 6, 1977.

Wexler, A., A Boundary Layer Interpretation of the Low-Level Jet, Tellus XIII (1961), 3, pp. 368-378, Aug 1961.

Yevseyev, P.K., Study of Sukhoveis, source unknown, pp. 106-130.

Yoshimura, Minoru, Chronology of the Bora-Day at Ajdovscina and Trieste, Climatological Notes, Dept. of Geography, Hosei University, Tokyo, pp. 64-78.

Yoshino, M.M., et al, "Bora regions as revealed by wind-shaped trees on the Adriatic coast," Local Wind Bora, M.M. Yoshino, Ed., University of Tokyo Press, 1976.

Yoshino, Masatoshi M., "Bora Studies: A Historical Review and Problems Today," Local Wind Bora, M.M. Yoshino, Ed., University of Tokyo Press, pp. 6-11, 1976.

APPENDIX A

MAPS

Map A-1 describes the boundaries of the regions identified as "Area I" and "Area II."

Maps A-2 (Eastern Europe) and A-3 (Soviet Union) show the general topography in these areas and include representations of selected locally-named winds described in the text. Each wind is identified by number as shown in the lists below. Predominant directions are indicated by arrows.

Mountain and Valley Winds.

		See Paragraph(s)
1.	Maloja	6.2.1, 6.5.1
2.	Liptowski	6.2.2

Foehn Winds.

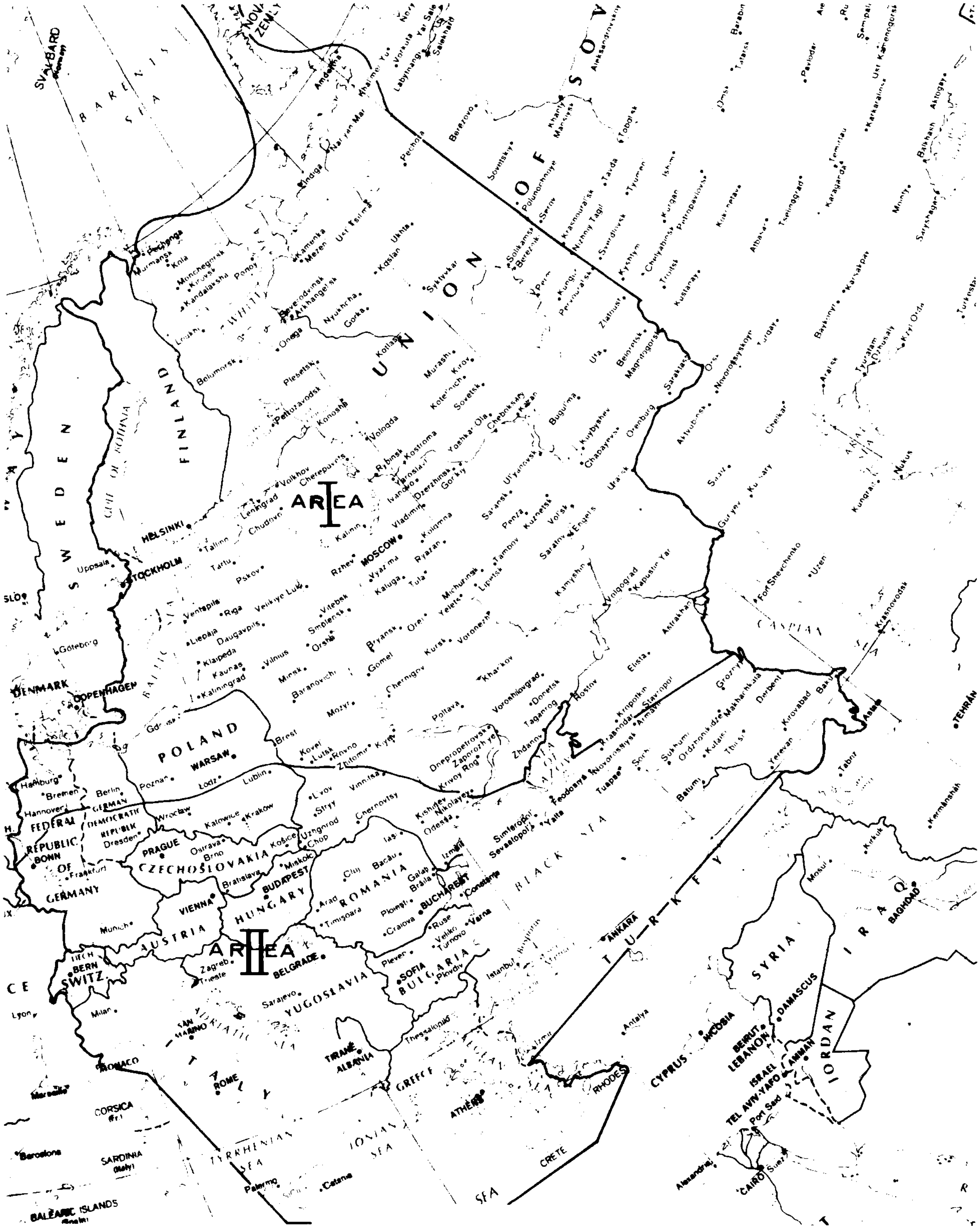
3.	Halny	6.3.1
4.	Orawski	6.3.1
5.	Ryterski	6.3.1
6.	Rymanowski	6.3.1
7.	Koszawa Orkoschava	6.3.2
8.	Sukhovei	5.3, 6.3.3

Bora Winds.

9.	Bise	6.4.2
10.	Boehmischer	6.4.4
11.	Crivetz	6.4.6
12.	Kossava	6.4.5, 6.5.3
13.	Liva	6.4.8
14.	Nemere	6.4.7
15.	Struma	6.4.10
16.	Vardarac	6.4.9
17.	Tramontana	6.4.1
18.	Polak	6.4.3, 6.5.2
19.	Novorossiysk Bora	6.4.12
20.	Novaya Zemlya Bora	5.4

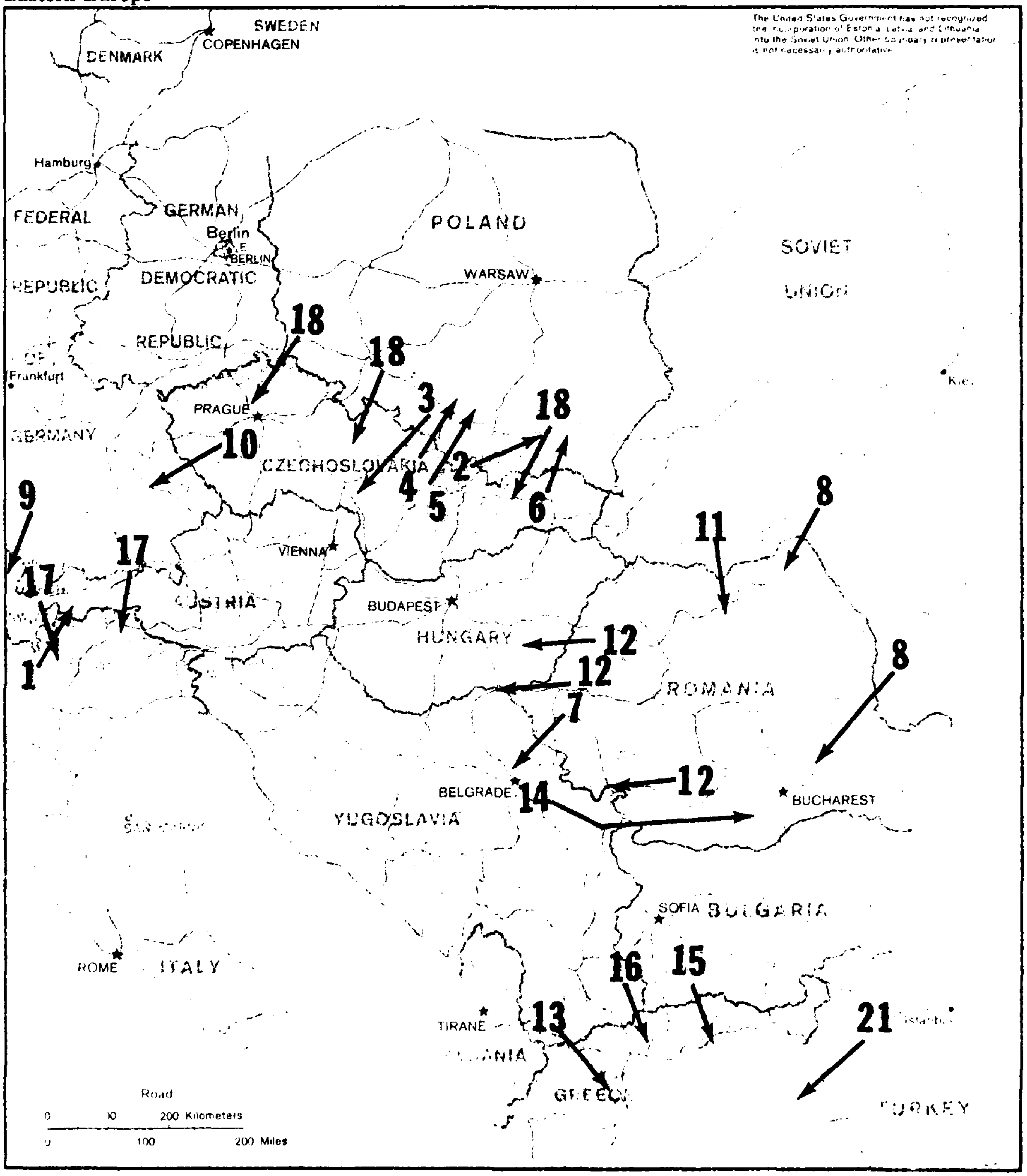
Jet Effect Winds.

21.	Dusenwind	6.5

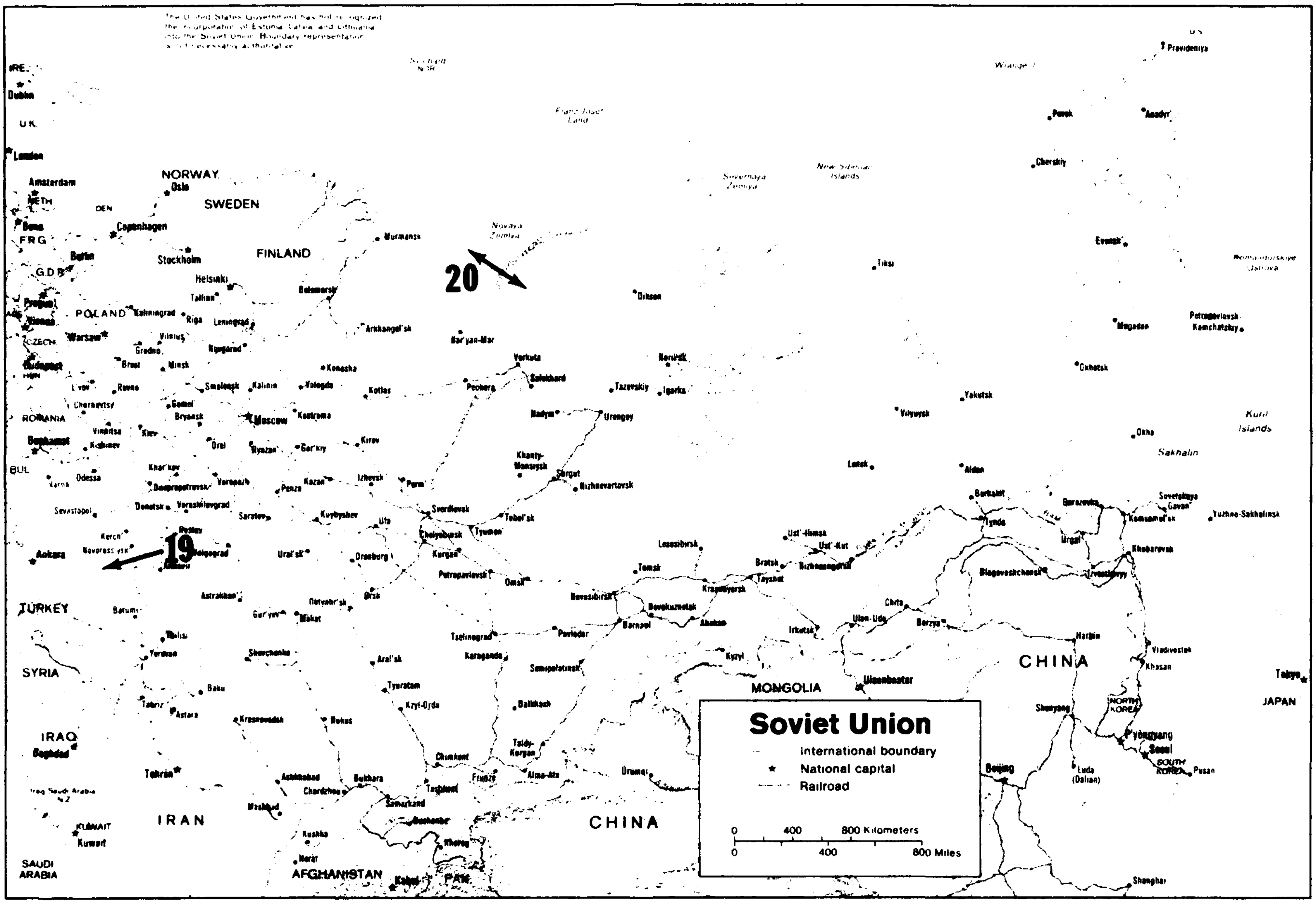


MAP A-1 AREA I AND II BOUNDARIES

Eastern Europe



MAP A-2 TOPOGRAPHY AND LOCAL WINDS, EASTERN EUROPE



MAP A-3 TOPOGRAPHY AND LOCAL WINDS. SOVIET UNION

APPENDIX B

DEFINITIONS

The following is an alphabetical list of local wind names and meteorological terms related to the development and description of local wind systems. Many local wind systems, although listed here, were not considered sufficiently signicant to be included in the text. An asterisk (*) indicates reference to Martyn Danuta, 1977.

Aberwind A warm foehn wind blowing out of the Alps in spring and causing snow to melt. Also called "Alpach" or "Aperwind"--used mostly in the Swiss Alps.*

Advection Horizontal flow of air at the surface or aloft--one of the means by which heat is transferred from one region of the earth to another.

Afer A southwesterly wind in Italy.*

Agestes Ancient Greek name for the northwest wind (included among the Etesian currents) of the Ionic Sea. Also called "Maistros" or "Maestro."

Albtalwind A mountain wind in the Alb Valley of Germany's southern Black Forest.*

Allerheiligen Wind "All-Saints Wind" (German) that blows in the Tyrols during "Indian Summer."*

Alpach See Aberwind.

Anabatic Wind The opposite of "katabatic wind." An upslope wind; term usually applied only when the wind is blowing up a hill or mountain as the result of local surface heating and apart from the effects of the larger-scale circulation. The most common type the "valley wind."

Ander A strong southerly wind over the southern portion of Lake Garda in southern Italy--also called andra.*

Antitriptic Wind A local wind, such as a land or sea breeze.

Apartkias Ancient Greek name for a dry, cold, northeast wind that occurs during the winter and has a continental origin.

Apeliotes Ancient Greek name for a dry, warm, east wind.

Aperwind *(Alps, especially Swiss Alps) A foehn wind that quickly melts the snow (aper, from Latin* apertus, "open"). See "Schneefresser" (snow eater).*

Aura A southwesterly wind in the southern Alps.*

Auster Antiquated term for the southerly wind (the Sirocco) on the Bulgarian coast; also called "Ostria."*

Austru From the Latin australis, "southerly wind." A dry, westerly, foehn wind and a southwesterly wind in southern Italy. Also spelled "Austrul."*

Aziab Local term for warm and humid winds above the Black Sea.*

Balaton Wind A breeze over Lake Balaton, Hungary, that often reaches 5-10 km inland.*

Bali A wind in the eastern part of Lake Garda, usually lasting 3 days (vent de Bali--dura tri di).

Batis See emvatis.

Bayrischer Wind "Bavarian Wind"; a local term for westerly winds in Upper Austria and a southerly wind in the Oetz Valley of western Austria. Also called Bayerischer Wind.*

Bise (Northwest Switzerland) A dry and cold north to northwest wind with mostly clear skies, found along the Alpine ridge from Basel to Geneva. Called "Bise Noir" when accompanied by dreary weather.

Bise Noire See Bise.

Blizzard (Also "Buran" or "Purga") A severe weather condition characterized by low temperatures and strong winds bearing great amounts of snow, mostly fine and dry, picked up from the ground.

Boaren A local wind over the Bay of Salo in Lake Garda, Northern Italy.*

Bodenwind (Ground Level Wind) A wind close to the ground or in the lower atmospheric layers.

Boehmischer Wind German for "Bohemian" or" Czech" wind. A cold, gusty easterly, similar to the bora, that descends into Bavaria and the Bohemian Forest. It occurs with a high over the eastern portion of central Europe.*

Bohemian Wind See Boehmischer wind.

Bonenti A humid westerly wind in Bulgaria that brings cloudy and overcast weather. Also known as the Karael.*

Bora See paragraph 4.3.1.

Bora Chiara Italian for "clear" or "cloudless" bora; A bora of anticyclonic origin connected with a high above the Balkans and over the Italian Adriatic coast. More often observed in winter when it brings dry, cloudless weather.*

Bora Circlonica A bora of strong and stable cyclonic origin; a northeasterly wind over the Italian coast that brings rainy weather or heavy snow and frost in winter. It occurs with a low over the central Adriatic. Also called "Bora Scurra."*

Boraccia A particularly strong bora along the Italian Adriatic coast. Also called "Boron."*

Borasco or Burrasca A central Mediterranean storm; Italian name for a "storm over the sea."*

Bora Scurra See Bora Circlonica.

Boreas Old Greek term ("wind from the mountains") for northerly winds. Also called "Borras." In the eastern part of the Mediterranean Sea, primarily in Greece, it means a wind from the mountains or one having a north-northeasterly or northeasterly direction.*

Borin A weak bora on the Italian Adriatic coast.*

Borino A low speed summer wind of thermal origin on the Adriatic Dalmation coast. Also a moderate northerly and northeasterly summer wind that occurs in the southern Italy's Bay of Taranto.*

Bornan A valley wind in the Drance Valley that spreads over the central part of Lake Geneva, Switzerland.*

Boron See Boraccia.

Borras See Boreas.

Bregenzer Fallwind An east or northeast wind with foehn-like characteristics; blows out of the Gebhards and Pfander mountains into the Bregenzer Bay (Bodensee Lake Constance) along the southwestern West German border. Most often seen in spring when it blows from the northeast. Also called "Ost Foehn" and "Falscher Foehn."*

Breva A valley wind that blows from the southern arms of northern Italy's Lake Como during the day upward into the Adda Valley (the Northern part of Lake Como). Also called "Breva di Lecco" (from the locale of Lecco) and the "Breva di Com" (from Como).*

Breva del Laggio A light wind blowing from the direction of Lake Lugano in northwestern Italy.*

Breeza di mare (Italy) Italian name for an onshore sea wind.*

Bruscha A northwestern wind in the Bergell Valley of the Swiss Alps. Also a valley wind in the Inn Valley (western Switzerland) or a northeastern valley wind in the Engadyne (Switzerland). It is associated with the advection of cold air from a high over northern France.*

Bryza Ladowa See Nocny Wiatr.

Buran A strong northeast wind in Russia and central Asia that resembles a blizzard. It occurs most frequently in winter. It is a very cold wind that lifts snow from the ground and severely restricts visibility. As such, it is called the "White Buran" or, on the tundra, "Purga". The buran also occurs, but less frequently, in summer, when it raises dust clouds.

Burga See Buran.

Buria Bulgarian term for bora.

Cap cloud See foehn wall.

Chortiatis A local katabatic wind that blows from the Chalkidike Mountains into the northeastern part of Salonika, Greece. Similar to the Wardalak (Vardar) wind, a type of bora.*

Charmsyn See Khamsin.

Crivetz A strong and gusty, severely cold northerly through easterly wind in Romania. Blows from the Ukraine. A type of bora. See paragraph 6.4.6.

Czech Wind See Boehmischer wind.

Davoser Talwind A valley wind in Davos, Switzerland.*

Downslope wind See katabatic wind.

Dimmerfoehn A very rare form of the foehn on the north slopes of the Alps; connected with a very strong southerly wind at great altitudes.*

Dramudana (Elephant Wind) A northeasterly wind in Bulgaria.*

Dusenwind A strong east-northeast wind that blows out of the Dardanelles into the Aegean Sea and penetrates as far as the island of Lemnos. Caused by a ridge of high pressure over the Black Sea. One of the purest examples of a jet effect wind.

Dynar Foehn See Dynarski Fen.

Dynarski Fen ("Dynar Foehn") A dry, warm northwesterly or westerly wind in the river valleys of the Sawa Basin from Sarajiwo to the Karawarken along the borders of Austria and Yugoslavia.*

Ekbatis See Emvatis.

Elerwind A wind in Sun Valley, north of Kufstein in the Tyrols.*

Embatis See Emvatis.

Emvatis (German for "importuning, pressing") A summer season sea breeze on the Greek coast that begins in Athens around 1000 LST. It brings cool breezes in the hot season. Also called "Tropaia," "Batis," "Ekbatis," "Embatis," "Emwatis," "Imbat," and "Imbatto."*

Emwatis See Emvatis.

Erler Wind A mountain wind in the Bavarian section of Austria's Inn Valley.*

Etesian A northerly wind that effects the eastern Mediterranean from May through October or November. Characterized by high speeds and directional consistency. See paragraph 6.6.3.

Etschwind A southerly wind in the Tyrol region of Austria.*

Eurakylon A northeasterly wind, often of storm force, on the southern coast of Crete.*

Euros Southeasterly winds with rain and squalls in Greece.*

Falscher Foehn See Bregenzer Fallwind.

Fall wind A strong, cold, downslope wind; differs from a foehn in that the air is initially cold enough to remain relatively cold despite the abiabatic warming during descent. The fall wind is a larger scale phenomenon than a "gravity wind" in that it requires an accumulation of cold air at high elevations.

Foehn A warm, downslope wind. See paragraphs 5.3 and 6.3.

Foehn cyclone A cyclone formed (or at least enhanced) as a result of the foehn process on the lee side of a mountain range. An example is the "Gulf of Genoa" low.

Foehn pause (also called "Sturmpause") A temporary cessation of a foehn at the surface, due to the formation or instrusion of a cold air layer that lifts the foehn above the valley floor. This often happens for a few hours in the early morning just before sunrise; it brings about rapid falls in temperature and increases in relative humidity that persist for an hour or more. A "foehn pause" is also defined as the boundary between foehn air and its surroundings.

Foehn storm A strong October foehn with violent storms, in the Bavarian Alps.*

Foehn wall The steep leeward boundary of flat, cumuliform clouds that form on the peaks and upper windward sides of mountains during foehn conditions. Also known as a "cap cloud".

Forano The term used for sea breeze in Naples.*

Forty Saint's Storm A southerly and stormy Greek wind that blows in March before the spring equinox.*

Free air foehn or free foehn See high foehn.

Furiani A strong, short-lived wind that varies between southeasterly and southwesterly in advance of a storm near the mouth of the Pad River, northeastern Italy.*

Gaign A mountain wind that induces formation of clouds above mountain peaks in Italy.*

Garbin A Sirocco-type wind of anticyclonic origin over the southern Adriatic and Aegean Seas; usually south southwesterly and found at the leading edge of a low pressure system.*

Garbis See Lips.

Gardij A general term for southerly winds in the Bay of Yalta in the southwestern USSR. A southeasterly wind is called "Punento-Gardij," the southwesterly wind the "Oster-Gardij."*

Garmach A southerly wind descending the northern slopes of Mount Elbrus, USSR, during fall and winter. This foehn-type wind causes a temperature increase in winter.*

Geneve A wind blowing over the southwestern shore of Lake Geneva (from the direction of Geneva) into the foothills of the Jura Canton in Switzerland.*

Giermich An infrequent foehn-type westerly or southwesterly wind in the southwestern portion of the Caspian Sea. It occurs an average of six times a year at Astara, USSR. In a typical year, there are four occurrences in winter and one each in spring and fall. Although rare, it causes pronounced temperature increases and drops in relative humidity.*

Girlovoy Wietie See Spedzajace Wiatry.

Glarner Wind A foehn-type wind from various southerly directions that descends from the Glaner Alps into Zurich, Switzerland.*

Goelitzer Wind A stormy, south-southwesterly wind that blows between the Ore Mountains and the Sudetem Mountains over the Zytava Depression and down the Oder-Nuisse River Valley. It occurs with a high over the Bohemian Plateau and a low over northern Germany.*

Graegos A Greek northeasterly wind, dry and warm in summer and cold in winter.*

Gravity wind (also called "drainage wind"; sometimes "katabatic wind") A wind, (or component thereof), directed down the slope of an incline and caused by greater air density near the slope than at the same levels some horizontal distance from it. The term is usually applied when the density difference is produced by surface cooling along the incline, as in the case of a "mountain wind". "Fall winds," on the other hand, are considered to be larger scale phenomena, as exemplified by the motion of cold air from an elevated interior toward an adjacent warm sea coast. The terms "gravity wind" and "katabatic wind" are sometimes considered synonymous.

Gravity lee wave See lee wave.

Greco Italian for "wind from the direction of Greece." A strong and stormy northeasterly bora-type wind in the central Mediterranean Sea, especially over Malta. Also a northeasterly wind connected with a very strong Adriatic bora that crosses the Appenine Penninsula and the Tyrrhenian Sea to extend as far as Corsica and Sardinia. Also called "Gregale" or "Gregolia."*

Gregale See Greco.

Gregori Wind An easterly wind in the Tyrol region of Austria and Italy that blows in April and March.*

Greus A northeasterly wind on the Bulgarian coast of the Black Sea.*

Grewo or Grewo-Tramontan See Klimat.*

Guxen A cold wind blowing out of the Swiss Alps.*

Halny A foehn wind in and around the Tatra Mountains of Poland and Czechoslovakia. See paragraph 6.3.1.

Heidelberg Talwind A nocturnal wind that blows into the Neckar River Valley near Heidelberg, Germany.

Hellespontias Ancient Greek term for a northeasterly Etesian-type wind that blows over the Black Sea, through the Dardanelles Strait region, then into the Aegean Sea. Also called "Ventus Hellesponticus."*

High foehn Also called "free foehn." The presence of warm, dry air above a layer of colder air at the surface, accompanied by clear skies and resembling foehn conditions. This condition is due to subsiding air in an anticyclone above a cold surface layer. In such circumstances the mountain peaks may be warmer than the lowlands. In mountain districts, this situation often precedes the foehn at the surface.

Hoellentaller A nocturnal wind that blows through the Hoellen Valley of Frybourg, Germany, in spring and summer. Also called the "Hoellenwind."*

Hoellenwind See Hoellentaller.*

Imbat A strong sea breeze in the Gulf of Smyrna and associated coastal regions. When the etesian wind is weak, the Imbat may extend 40 km inland. At Izmir, Turkey, for example, it normally blows 20-25 days a month from April to October. See Emvatis.*

Imbatto Italian for "collision, obstacle, obstruction." A summer sea breeze over the Adriatic coast, especially in the Dalmatia regions of Yugoslavia. See Emvatis.*

Imbattu A sea breeze in Sicily.*

Inferno Italian, "wind from the underground." A daily southeasterly wind (valley wind) in Lago Maggiore, northwestern Italy. Also called "Inverna."*

Inverna See Inferno.

Jivovec Czechoslovakian term for a northerly wind that contributes to the formation of hoarfrost.*

Jochwind A local valley wind that extends into the Tauern Pass in the Tyrol region of Austria.*

Jug A southwesterly wind in southern Dalmatia, Yugoslavia, particularly in spring and autumn during periods of intense cyclonic activity. Initially moist and warm, it loses its moisture in the Sava Valley from Karawanken to Sarajiwa as it ascends the Dynar Mountains. The resulting dry and warm wind on the lee side of the mountains is called the "Dynar Foehn."*

Karael See Bonenti.

Karajol Turkish, "wind from the land." A westerly wind on the Bulgarian coast that lasts 1 to 3 days, primarily in summer; usually accompanied by precipitation.*

Karstbora A local term for the bora on the Yugoslavian coast.*

Katabatic wind Any wind blowing down an incline; the opposite of "anabatic wind". If warm, it is called a "foehn"; if cold, it may be a "fall wind" (the bora), or a "gravity wind" (mountain wind).

Kercha See Napedzajacy Wiate.

Kerezak A southwest wind in the Don Valley of southwestern USSR.*

Khamsin A term for a strong Sirocco-type wind over Malta. Also called the "Charmsyn.."*

Klimat A cold winter wind blowing from the mountains along the north coast of the Black Sea. Sometimes connected with the passage of a front, but at the same time having the character of a squall over the southern slopes in the area of Nikolskiy Sad, USSR. The Klimat that blows from the northeast is called "Grewo" or "Grewo-Tramontan", an indication of a storm over the Black Sea.*

Koszawa or Kossava A cold east or southeast wind that affects northeaster Yugoslavia, Hungary, and the southern part of the Romanian Plains. See paragraph 6.4.5.*

Kroatenwind See Krowotenwind.*

Krowotenwind German, "wind from Croatia." A cold and damp southeasterly wind, often accompanied by fog, blowing for several days in Vienna, Austria. Development is associated with a low over the northern Adriatic. Another name for it is "Kroatenwind."*

Kvarnero See Quarnero.

Kynuria A cold mountain wind blowing during the evening from the Parnon Mountains of southern Greece to the coastal regions.*

Labech A moderate, sometimes southeasterly wind that usually occurs during autumn and winter in the Swiss-French Alps.*

Lake breeze or wind Similar in origin to the "sea breeze," but generally weaker. It blows onshore off the surface of a large lake during the afternoon and is caused by the same land/water temperature difference that causes the land and sea breeze system. Along with water area, lake depth is an important factor; in summer,a shallow lake warms up more rapidly and is therefore less effective as a lake breeze source than a deeper lake would be.

Lampaditas Greek for "torch-bearing," used to describe the Sirocco on the Island of Zakynthos in the Aegean Sea. A hot and dry southerly wind, colored white, yellow, or red from Sahara dust. Although it blows throughout the year, it occurs most frequently in spring.*

Land Breeze An offshore breeze (from land to sea); caused by the temperature differential when the sea surface is warmer than the adjacent land. Usually blows from land to water at night, alternating with the "sea breeze" that blows in the opposite direction by day.

Lee wave Also "mountain wave" or "gravity lee wave". Any wave disturbance caused by, and therefore stationary with respect to, a barrier in the fluid flow.

Lenzbote Term for the springtime Alpine foehn that causes rapid melting of the snow.*

Lenticular clouds Associated with strong vertical oscillations of air flow as it moves across orographic obstacles. The band of lenticular clouds parallel to a mountain may be the only clue to the existence of a "mountain wave." Low-level orographic "lenticular clouds" may look like ordinary stratocumulus, but careful observation will reveal individual lumps forming on the upwind side, moving through the cloud mass, and dissolving on the downhill side.

Lenantera An easterly wind that brings rainy and cloudy weather; associated with a bora over the northern Adriatic.*

Lenanti Term for an easterly wind over the Bulgarian Black Sea coast.*

Lenantis Term for easterly winds in Greece.*

Leukonotoi Greek, "white wind." Ancient Greek term for a southerly wind; the opposite wind is called the "Notos."*

Libeccio Italian term for a southwesterly wind over the Italian coast of the Ligurian and Tyrrhenian Seas.*

Lips Greek, "southwesterly wind." Ancient Greek term for a sea breeze in Athens or a light southwesterly wind bringing precipitation. Other names are "Livas" or "Garbis."*

Liptowskie Wiatry "Liptowski Winds," the mountain or valley winds that flow through the Morskie Oho depression in southeastern Poland.

Listopad A southwesterly wind in the region of the White Sea; appears from the end of August into the winter.*

Livas   A westerly foehn-type wind blowing in May from Pindos onto the Thessalonika Plain in Greece. Another name for it is "Lips."*

Ljula   Slovanic, "jug" or "wind out of the south." Local name for the foehn in Carynthia of northwestern Yugoslavia.*

Lodos   "Bleaching wind." Term for warm southeasterly to southwesterly winds over the Bulgarian Black Sea coast during summer and fall.*

Luganot   A strong southerly or southeasterly wind over Lake Garde in southern Italy.*

Maestrale   Italian, "maestro" or "master." A steady southeasterly wind bringing good weather in summer, especially to Sicily.*

Maestro   Italian term for "Mistral." A northwesterly wind with good weather, observed primarily in summer over the Adriatic and the Aegean Seas. It occurs with a low over the Balkans.

Maistra   A westerly wind with cold weather in the the Black Sea region.*

Maistros   See Agestes.

Maistrus   A northwesterly wind in Bulgaria.*

Maloja Wind   A variation of the mountain or valley wind. See paragraph 6.2.1.

Mamatele   A weak southwesterly wind in Sicily; a specific form of the Mistral.*

Marenco   An east-southeasterly wind over Lago Maggiore in Northern Italy.*

Marinon   Southerly autumn winds over Lago Maggiore.*

Mergozzo   A northwesterly wind over Lago Maggiore.*

Midnight Wind   See Mitternachtswind.*

Mietiel   Russian, *"metel," for blizzard or snowstorm.**

Mistral   A strong, squally, cold and dry wind; the combined result of the basic circulation, a fall wind, and a jet-effect wind.

Mitternachtswind   A southerly nocturnal mountain slope wind; blows the latter half of the night with a high over Starnberg, Lake Ammer, and the Wurm region of Bavaria. Also called "Midnight Wind."*

Moazagoth   A strong wind blowing across the Sudeten Mountain ridge into northeastern Germany during the colder months of the year, especially in autumn.*

Moalan   A breeze blowing from Aeve toward Genoa, Switzerland.*

Montagnere   A wind descending out of the southern Alps in early morning, blowing toward the Mediterranean Sea.*

Monterese   a gusty northerly with a bora character, blowing from Monte Gorgano into the Bay of Manfedonia in eastern Italy.*

Montis   Local northerly and northeasterly wind blowing from Bardoline toward Peschiera and Sirmione over Lake Garda, Italy.*

Morena   A humid northerly wind in the region of Baku, USSR, that greatly reduces visibility; occurs with a low over the Caspian Sea and a high to the north of Baku.*

Morget   A strong northerly land breeze from 1500 to 0900 LST over the northern banks of Lake Geneva, Switzerland. During winter and fall, it may blow all day. The lake breeze equivalant is called "Rebat."*

Morianik   Term for a sea wind in the White Sea region. Another term is the "morianka."*

Morianka   See Morianik.

Mountain Breeze   A breeze that blows down mountain slopes due to gravity flow of cooled air; same type as "gravity", and "katabatic" winds.

Mountain or Valley winds A system of diurnal winds along the axis of a valley; they blow uphill or upvalley by day, downhill or downvalley by night. They prevail mostly in calm, clear weather. The upvalley component (or "valley wind") usually sets in about a half hour after sunrise and continues until about a half hour before sunset, reaching its greatest strength at the time of maximum insolation. On southerly-facing slopes, it may reach 6 m/s (14 mph), while on northerly-facing slopes it may be barely noticeable. It has a depth of some 150 m (500 ft), increasing uphill. It is created by the temperature difference between the air heated over the slopes and the free air at the same height. Air flows radially away from the summit and returns to the plains. The downvalley component (or "mountain wind") at night is due to nocturnal cooling and is somewhat weaker (up to 4 m/s or 8 kts), but is usually stronger a few hundred meters above the ground than at the surface.

Mountain gap wind A local wind blowing through a mountain gap. The term was introduced by Scorer (1952) to describe the surface winds blowing through the Straits of Gibraltar. When the air stratification is stable, as it usually is in summer, air tends to flow through the gap from high to low pressure, emerging as a "jet," with large standing eddies. The excess of pressure on the upwind side is attributed to a pool of cold air held up by the mountains. See "venturi effect."

Mountain wave See lee wave.

Mountain wave cloud Cloud caused by vertical motion set up by the air stream as it crosses hills, mountains, or ridges. The result is an orographic cloud with distinctive features from which some of the properties of the wind (airstream) may be deduced. Orographic clouds move very slowly, if at all, but winds at the cloud level may be very strong. An indication of wind movement through such a cloud may be obtained by following identifiable portions of the cloud mass as they move from one end of the cloud to the other and while the cloud mass as a whole remains stationary. Orographic clouds may form below, at, or above the top of the obstacle. Types of orographic clouds are "foehn walls", "cap clouds", "lenticular clouds", or "rotor clouds."

Napedzajacy Wiatr "Driving wind," a term for a wind that blows counter to the flow of a river and results in a rise in the water level (by several meters) at the river's mouth. Observed in Leningrad at the mouth of the Neva when low pressure systems move across the Baltic from the west or southwest toward the east. These winds are especially fierce when they blow over the relatively narrow and flat Gulf of Finland. In the Don River Valley of the USSR they are known as "Kercha," Russian for "driven winds."*

Nemere A cold and strong westerly or southwesterly wind that blows down the Danube Valley, particularly in Transylvania, and on the Rumanian Black Sea coast. It arises on the trailing edges of a low over the Black Sea. It is accompanied by snow and may reach blizzard intensity with significant temperature drops. Also called the "Nemero."*

Nemero See Nemere.

Nizowka Russian term for valley winds.*

Nocny Wiatr General term for local winds blowing during the night. Other terms are "Waitr Gorski" (mountain wind) and "Bryza Ladowa" (land breeze).*

Nord A very strong and constant northerly wind at Baku, USSR. It is dry and cold with high speeds (up to 40 m/s or 76 kts) that may last 1 to 2 days, occasionally 3 to 4 days. Winds may be dust laden as they cross the Apsheronsk Pass. Wind speed increases at the foothills of the Caucus Mountains. Required meteorological conditions are similar to those for the Mistral.*

Nordfoehn A foehn over the southern slopes of the Alps.*

Notos See Leukonotoi.

Ora A strong wind over the northern part of Lake Garda in northern Italy. The powerful Vinezzu wind occurs over the southern part of the lake at the same time.

Orawski A southwesterly or southeasterly foehn-type wind occurring in the Tatra Mountains of Poland and Czechoslovakia. See paragraph 6.3.1.

Orographic Lifting The physical lifting of an air current as it passes over mountains or other orographic barriers.

Ost Foehn See Bregenzer Fallwind.

Ostria A humid and warm southerly and southeasterly wind over the Bulgarian Black Sea coast; usually a herald of worsening weather.*

Oster-Gradiji See Gardij.

Ostro Italian term for southerly winds.*

Paesa A strong north-northeasterly wind over Lake Garda at Torbole, Northern Italy.*

Paesano A nighttime mountain wind over Lake Garda.*

Pazdiernik A northerly October wind in the northern European part of the Soviet Union.*

Pfander Wind A "fall wind" produced by the air flow down Pfander, a 700-meter ridge near Lake Constance. See fall wind.

Pobiercznik A southeasterly wind in the region of the White Sea.*

Polak A cold fall northeasterly in northeastern Czechoslovakia that takes on Bora characteristics. See paragraph 6.4.3.*

Poludenik A southerly wind over the White Sea.*

Ponente A sea breeze in western Italy.*

Ponentis A term for a mild westerly wind with good weather.*

Poriaz A strong northeasterly wind over the Black Sea near the Bosporus.*

Porlezzina An easterly wind blowing from the Bay of Polezzina over Lake Lugano on the Italian-Swiss border.*

Posjemok A term for severe blizzards in the Soviet Artic.*

Punento-gardiji See Gardij.

Purga See Buran or Blizzard.

Pyrhenerwind A foehn in the Austrian Alps.*

Quarnero Local name for a very strong bora in the eastern part of the Istria Peninsula. The term is from the Kvarnero Strait, where "Kvarnero" is another name for it.*

Raffiche General term for a wind from out of the mountains or a strong bora in the Mediterranean Sea region. Called "Refoli" on the Istria Peninsula in northern Yugoslavia and "Reffoli" in the region of Lake Garda, Italy.*

Raggiatura Term for strong, violent wind gusts along the west coasts of Italy and Sicily.*

Rampinu Term for a land breeze in eastern Sicily.*

Rebat A lake breeze over Lake Geneva, Switzerland, normally occurring from 1000 to 1600 LST during April through September. It blows on an average of 10 to 12 days a month.*

Reffoli See Raffiche.

Refoli See Raffiche.

Reshabar A strong wind from the northwest over the Caucasus Mountain range between the Black and Caspian Seas.

Riefne A strong storm over Malta.*

Rotor Cloud A cloud that shows evidence of strong and sometimes violent turbulence. It constantly forms and dissipates downwind of the ridge line. It appears to rotate, with the upper portion moving forward and the lower portion backward, toward the ridge.

Rymanowski Wiatr "Rymanow Wind." A foehn wind in the Tatra Mountains. See paragraph 6.3.1.*

Ryterski Wiatr "Rytro Wind." A foehn in the Tatra Mountains. See paragraph 6.3.1.*

Sarca A strong northerly wind over Lake Garda in northern Italy.*

Scharnitzer Wind A long-lived and cold northerly or northwesterly wind blowing out of the Scharnity Pass in the Tyrols of Austria and Italy.*

Schlern Wind A westerly mountain wind that passes through the Etsch Valley near Bozan in the southern Tyrols of Italy.*

Schneefresser German for "snow eater." Term for Alpine foehn; see Aberwind.*

Scirocco A hot and dusty southerly wind as it originates over the Sahara Desert, but picks up moisture as it crosses the Mediterranean Sea. Affects the Adriatic, Aegean, Ionian, and Mediterranean coastal areas by bringing low clouds and continuous rain. See paragraph 6.6.1.

Scirocco Chairo Italian for "cloudless Sirocco," one of anticyclonic origin that brings cloudless weather during spring, early summer,and autumn.*

Scirocco Maricio Italian for "lazy Sirocco," or one that disappears for short periods; may be accompanied by rain.*

Scirocco Scuro Italian for "dark" or "gloomy" Sirocco, one of cyclonic origin, usually blowing out of the southeast or south-southeast and bringing clouds and rain.*

Sea breeze A coastal on-shore wind system that blows from sea to land. Caused by the temperature difference between the colder sea surface and the warmer adjacent land. Usually blows on relatively calm, warm, sunny, summer days. Alternates with the opposite, usually weaker, nighttime "land breeze."

Sechard A foehn over Lake Geneva, Switzerland.*

Seefelder Wind A wind blowing out of Telfs in the Inn River Valley and over the Seefeld Highlands in the northern Austrian Tyrols.*

Sequin A sea breeze in the southern Alps that changes direction with the sun.*

Serokos A southeasterly wind over the Bulgarian coast.*

Siebengebirgswinde A northeasterly nighttime wind (mountain wind) that blows out of the Siebengebirge near Bonn and Beuel, West Germany.*

Siffanto A southwesterly wind that blows with occasional great force over the Adriatic Sea.*

Simmoom or Simoon A Sirocco-type wind--hot, dry, and dust-laden--that blows over the middle and southern portions of the Mediterranean.

Sirocco A dry and dusty desert wind that blows from the south or southeast across Turkey in spring, and occasionally in Autumn. See paragraph 6.6.2.*

Sirocco Levant An easterly or northeasterly wind in the Mediterranean Sea and Black Sea basin.*

Sivash See Spedzajace Wiatry.

Siwierko A cold easterly wind blowing from Siberia toward the Volga River in the vicinity of Volgograd, USSR.*

Skiron A northwesterly wind, cold in winter and warm in summer, that blows over the Isthmus of Corinth between Megara and Corinth, Greece, into the Gulf of Saronikos.*

Spedzajace Wiatry Polish for "driving wind," or winds blowing in accordance with the direction and course of a river. Such a wind on the Sea of Azow coast is called a "Sivash," while at the mouth of the Don River, USSR, it is called the "Girlovoy Wietie."*

Steppenwind A cold northeast wind that occasionally blows into Germany from the Russian steppes.

Struma A cold winter wind that descends down the Struma River valley in southern Bulgaria (and the Strimon River valley in northern Greece) to the Strymonic Gulf in the Aegean Sea. See paragraph 6.4.10.*

Sturmpause See foehn pause.

Suchowiej Russian, "dry wind." See Sukhovei, paragraph 6.3.3.*

Sudois A southwesterly wind over Lake Geneva, Switzerland.*

Suer A strong south-southwesterly wind over Lake Garda, northern Italy.*

Sukhovei In Russia, a hot, dry wind caused by subsidence from an upper-level anticyclone ("free foehn"). Most common in the Caucasus region and areas of the Russian plain just north of the Black Sea. Extremely well-developed Russian Sukhoveis may penetrate as far southwest as the Black Sea coastal plains of Romania and Bulgaria. In Hungary, western Bulgaria, and Romania, a northerly or northeasterly foehn wind. See paragraphs 5.3 and 6.3.3.*

Szalonik Polish for "madness, rage." A southeasterly wind on Lake Ilmen, blowing from the mouth of the Shelon River in the northwestern USSR. Caused by lows moving along the northern coastline of the Soviet Union.*

Szelonik A southwesterly wind in the region of the White Sea.*

Szilok A southerly wind over the western coasts of Yugoslavia, Albania, and Greece.

Talmacs See Turnu Rosu.*

Talmescher See Turnu Rosu.*

Tarantata A strong northwesterly breeze over the Mediterranean Sea.*

Tauernwind A mountain wind in upper Carynthia, Austria, descending out of the Tauern Mountains.*

Thalwind German, "valley wind." A pleasant valley wind in Germany.*

Thriaskias Ancient Greek term for northwesterly winds blowing out of Thrace in northeastern Greece and over the Aegean Sea.*

Tivano A nighttime mountain wind blowing over northern Italy's Lake Como. The corresponding valley wind is called "Breva."*

Tormenta Strong northeasterly to westerly summer winds in the Gulf of Taranto, Italy, accompanied by storms.*

Tosca A southwesterly wind over northern Italy's Lake Garda.*

Traersu A strong easterly wind on Lake Garda, near the towns of Manerba and Moniga.*

Tramontana Italian for "wind from behind the mountains." A bora-type wind in northern Italy. See paragraph 6.4.1.*

Traversier Hazardous winds over the Mediterranean Sea.*

Tropaia See Emvatis.

Tsiknias Frequent bursts of wind over the southern slopes of islands in the Aegean Sea during periods of the Etesian wind.*

Turkenwind German for "Turk's wind." A term for a foehn in the northern Tyrols of Austria.*

Turnu Rosu A southerly wind, similar to the foehn, blowing over the Transylvanian Highland from the southern Carpathians, then across the Red Tower Pass. In the vicinity of Ort Nazy-Talmacs, near Herman, it is called "Talmacs" or the German "Talmescher Wind."*

Upslope wind See anabatic wind.

Valley Breeze See mountain or valley winds, anabatic winds.

Vardar See Chortiatis.

Vardarac A cold, dry northerly blowing along the Vardar River valley into the Gulf of Salonika. See Chortiatis and paragraph 6.4.9.

Vaudaire Northerly foehn winds blowing from the direction of Canton Vaud (Waadt) over Lake Geneva, Switzerland.*

Vent da Mut A strong, humid wind over Lake Garda in northern Italy.*

Vent d' Italie French for "wind out of Italy." A northeasterly wind blowing along the French-Italian Border.*

Vento di Sotto Breezes blowing upwards into Lake Garda in northern Italy.*

Venturi effect An effect that results in increased wind speeds as air is forced through a through narrow mountain pass or gorge. See paragraphs 5.5 and 6.5.

Ventus Hellesponticus See Hellespontias.

Viehtauer Wind A nighttime mountain wind descending from the Hoellen Mountains, through the Traun Valley, and across Lake Traun in Upper Austria.*

Vinezzu A southerly wind over the southern part of northern Italy's Lake Garda. The powerful Ora wind (which see) occurs over the northern part of the lake at the same time.*

Vintschgauer A nighttime mountain wind blowing from the south in the Oets Valley of the Tyrols; it blows from the direction of the town of Vintschgau.*

Visentina Strong easterly winds over Lake Garda in Northern Italy.*

Vorias A recent term for the ancient "Boreas" wind; a cold, humid northerly that occurs in winter over the Aegean Sea.

Wardarak See Chortiatis. Other names used are "Vardar," "Vardar Wind," "Vardarac," and "Wardaer.".*

Wardarec See Wardarak or Chortiatis.

White Buran See Buran.

Wiatr Efektu Tunelowego Polish, "jet effect wind." See paragraph 4.3.3.*

Wiatr Gorski Polish, "mountain wind." See Nocny Wiatr.*

Wiatr Halny Polish, "wind out of deep, narrow valleys or ravines." The term for the foehn in the Polish Tatras and in lower Galicia. It often appears in spring and winter.

Wiatr Jugowy Polish colloquial term for a winter wind blowing from the south.*

Wiatr Lawinowy Polish, "avalanche wind." A surge of air caused by an avalanche or rock fall; its force may equal that of a cyclone.*

Wiatr Lodowcowy Polish, "glacier wind." A wind arising from the influence of the temperature difference between the air and the surface of a glacier. These winds reach their maximum speeds just before sunrise and again just after sunset at about the 2 m level above the glacier.*

Wiatr Przeleczowy Polish for "pass wind." The result of a daily valley wind blowing upward to a ridge, then through a pass where its speed increases. As it falls into the next valley, it creates an anomalous wind.*

Wiatr zst Puj cy Polish for "descending wind."*

Wiatr Gorshi See Nocny Wiatr.

Wisper A well-developed, nighttime easterly mountain wind . Blows from the western part of the Taunus Mountains down the Wisper Valley into the middle Rhine Valley of Germany.*

Wjuga A cold northerly or northeasterly wind that usually blows for 3 days over the steppes of European Russia.*

Young A hot, dry wind over the Mediterranean Sea.*

APPENDIX C

COLLOQUIAL WIND NAMES BY AREA

Many of the local wind names listed here by area were not considered sufficiently significant to be included in the text.

ADRIATIC, DALMATIA

Bora	Imbatto
Bora Chiara	Kvarmero (Quarmero)
Bora Circlonic	Levantera
Boraccia	Maestro
Borino	Neffiche
	Siffanto

AEGEAN SEA

Imbat	Tsiknias
Lampadito	Vorias

ALBANIA

Szilok

ALPINE COUNTRIES

Aberwind	Foehn
Alpine Foehn	Lenzbote
Alpine Wind	Shneefresser (Snow Eater)
Auro	Seefeld Wind
Bavarian Wind	Tauren Wind
Bruschn	Turkish Wind
Dimmerfoehn	Vintschgauer or Vintschger

AUSTRIA

Allerheiligen Wind	Ljuka
Bavarian Wind	Ober
Bregenz fall-wind	Pfander Wind
Dynarski Fin	Pyrhenerwind
Elerwind	Scarnitzer Wind
Etschwind	Suflder
Gregori	Tauern Wind
Hungarian Wind	Turkenwind
Jauk	Utes Wind
Joch Wind	Vintschgauer Wind
Krowotenwind	Vintschgauer or Vintschger

BLACK SEA

Azieb	Poriaz
Maistra	Sirocco Levant

BULGARIA

Auster	Maistrus
Bonenti	Meltem
Dramundana	Ostria
Greus	Quarajel
Karajol	Struma
Levanti	
Lodos	

CZECHOSLOVAKIA

Jinovec	Sever
Polak or Polake	Vychod
Poledne	Zapod Pulnoc

EASTERN PRUSSIA

Bernsteinwind (Amber Wind)

GERMANY (NORTH AND CENTRAL)

Alb Valley Wind	Moazagoth
Elb Valley Wind	Siebengebigsnwinde
Goerlizen Wind	Rhien Wind
Heidelberg Talwind	Wisjurwind
Hoellentaller	

GERMANY (ALPINE)

Boehmiescher Wind
Bregenxer Fallwind
Dimmerfoehn Midnight Wind
Erler Wind
Foehn
Foreland
Mittersnachtwind
Pfander Wind
Thalwind

GREECE (ANCIENT)

Agestes
Aparktias
Apeliotes
Boreas
Etesian
Euros
Euryclydon (or Eurskylon)
Forty Saint's Storm
Hellesportias
Hesperos
Kaikias
Leukonotoi
Lips
Notos
Olympis
Onchesmilis
Ornithiai (Bird Wind)
Skiron
Thraskias
Tropaia
Vultrunus
Zephyros

GREECE (NEW)

Chortiatis
Dussenwind
Embatis (Emvatis)
Eurakjlon
Garbis
Gabin
Graegos
Kabameltem
Karpusmeltem
Kirasmeltem
Kznuria
Lampaditas
Livas
Megas
Miltemia
Notia
Ostria
Ponentis
Sirocco
Sirocco Levant
Struma
Szilok
Usummeltem
Vardarac (Wardanak)
Vorias

HUNGARY

Balaton Wind
Kossava
Ungarischer Wind

ITALY

Adiac Wind
Andro (Ander)
Austru
Bali
Boaren
Breva
Breva del Laggio
Brizza di Mare
Dmbatten
Dnferno
Furian
Gaign
Grecale (Gregale)
Greco
Khamsin
Levante
Libecco
Luganot
Mastrale
Maesto
Moledetto Levante
Momatele
Marenco
Marinon
Mergozzo
Montagnere
Monterese
Montis
Mordfoehn
Ora
Paesa
Paesano
Ponente
Porlezzina
Raggiatura
Rampinu
Reffolli
Rufne
Sarca
Sarva
Schlern Wind
Sopero (Sover)
Scirocco
Scirocco Morcio
Scirocco Scuro
Seguin
Suer
Septentrio
Tivano
Tormenta
Tosca
Traersu
Tramontana
Vent da Mut
Vent d' Dlatie
Vento di Sotto
Vinezza
Visentina

MEDITERRANEAN SEA

Scirocco	Travirsier
Sirocco	Young
Tarantata	

POLAND

Liptowski Wind	Ryterski Wiatr
Polak	Siwier
Rymanowski Wiatr	Wiatr Halny

ROMANIA

Austru	Rotenturm Wind
Crivetz	Turnu Rosu
Menere	Talmesch Wind

RUSSIA

Buran	Morianik
Barnach	Napedzajacy Wiatr
Biermich	Nizowka
Kirezak	Nord
Klimat	Novorossikhsk Bora
Listopad	Pazdiernik
Metel	Posjemak
Mietiel	Purga
Morena	Sarma

SWITZERLAND

Bise	Labech
Boron	Maloja Wind
Bruscha	Molan
Chur Expriss	Murget
Davoser Talwind	Rebat
Geneva	Sechard
Glarner Wind	Sudois
Guxer	Vanaire
Joran	Walliser (Valois)

YUGOSLAVIA

Jug Nefoli	
Jarstbora	Szlok
Ljuka	Vardarac

APPENDIX D

A MATHEMATICAL SOLUTION OF MOUNTAIN OR STANDING WAVE LENGTHS

Scorer (1949, 1953, 1954) found that stability and wind speed are fundamental to the mathematical solution of a mountain or standing wave length. Wave length (λ) is defined by the equation:

$$\lambda^2 = [g\beta/\upsilon^2] - [1/\upsilon]\,[\delta^2\upsilon/\delta z^2] \qquad (1)$$

where: λ = wave length
g = acceleration of gravity
z = height measured upwards
υ = horizontal wind component normal to the mountain ridge
$\beta = (1/\theta)\,(\delta\theta/\delta z) = (1/T)\,(\gamma_d - \gamma)$ = static stability,

where: θ = potential temperature
T = absolute temperature
γ_d = adiabatic lapse rate
γ = actual lapse rate

The second term in the equation's expression for λ concerns the rate of change of wind shear with height. If the wind speed is constant or changes uniformly with height, this term is zero. It assumes importance only when wind shear changes rapidly with height; this is rarely the case, except over shallow layers or in the upper troposphere near jet stream cores. Further, this term is not always easy to evaluate with the desired degree of accuracy from actual wind observations. For practical purposes, then, only the first term is usually considered in computing λ. Therefore, we can simplify the original equation to:

$$\lambda = [g\beta/\upsilon^2]^{1/2} \qquad (2)$$

A 1957 study by Corby gives an idea of the magnitude of the variation of λ with height as observed in wave conditions. Corby's study examined 37 mountain wave reports made by British European Airways pilots. On the average, the minimum of λ aloft was found to be one-ninth of the maximum below. This relationship was confirmed by observations made at St. Auban-sur-Durance on 25 January 1956 when vigorous waves occurred to the lee of the Lure Mountain ridge. Table D-1 gives values of $g\beta/\upsilon^2$ at different levels from 1 to 10 km. The average value of $\lambda^2 = g\beta/\upsilon^2$ between 1 and 5 km is again about 9 times that found between 5 and 10 km.

The one-ninth λ^2 decrease per 5 km vertically should not be used as a quantitative limit in forecasting wave length. However, it does give an idea of the size of the decrease possible during certain wave situations. The values given above are probably greater than are likely to be found under average wave conditions.

TABLE D-1. Values of $g\beta/\upsilon^2$ at St. Auban-sur-Durance on 25 January 1956.
A standing wave train was observed to the lee of Montagne de Lure.

Altitude (m)		Altitude(m)	
1000 - 1500	2.20	5500 - 6000	0.42
1500 - 2000	0.64	6000 - 6500	0.04
2000 - 2500	0.49	6500 - 7000	0.16
2500 - 3000	0.55	7000 - 7500	0.04
3000 - 3500	0.49	7500 - 8000	0.02
3500 - 4000	0.25	8000 - 8500	0.02
4000 - 4500	0.25	8500 - 9000	0.02
4500 - 5000	0.12	9000 - 9500	0.00
5000 - 5500	0.00	9500 - 10000	0.00

According to the basic equation, the wavelengths of standing waves must lie between the greatest and smallest value of $2\pi/\lambda$. This means that light winds and stability are associated with short wavelengths. Conversely, strong winds and instability are associated with long wavelengths. Wavelength is more sensitive to variations in wind speeds than to lapse rates. Wavelengths, therefore, increase almost linearly with the mean wind speed.

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